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Culver City, California

Statement 2. Monitor: Aeronautical Systems Division
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5 Dec 67

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(14) HTC-285-13-(62-13)-Vol 2

[redacted] (15) AF 33(600)-30271

(6) HOT CYCLE ROTOR SYSTEM,
VOLUME II.
ROTOR BLADE STRUCTURAL ANALYSIS,

(11) Mar[redacted] [redacted]62

(12) 307p.

(10) J. Needham, L. Earle
and D. W. Nicholls.

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HUGHES TOOL COMPANY -- AIRCRAFT DIVISION
Culver City, California

For

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VOLUME II

5.2 ROTOR BLADE STRUCTURAL ANALYSIS

CONTENTS

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5.2 ROTOR BLADE

5.2.1 Introduction

& Hot Cycle Rotor Blades.

In the design of the Hot Cycle Rotor blades there were three items of primary importance ~~which~~ had to be considered in the design flapwise and chordwise natural frequency requirements, ability to withstand the extreme temperatures imposed on the structure by the hot gases, and reliability of the structure to provide safety of flight under the vibratory load conditions always present in helicopter rotor blades. Based on these considerations the blade construction was made as simple and straightforward as possible.

Two titanium spars, continuous from the blade root to the tip, are designed to resist centrifugal force loads, flapwise and chordwise bending moments, and an unbalanced spanwise duct pressure load. The remainder of the blade basic structure consists of segments (approximately one foot in length in the constant section region from Station 90 outboard to the tip - see Figure 5.2-1).

The main segments, connected by flexible couplings, act as spacers between the front and rear spars and contain the hot gas ducts. Torque and chordwise shear loads are carried by these segments. Trailing edge and nose cap sections which attach to the main segments with flush screws complete the blade airfoil. Since the ducts are an integral part of the main segments, the design of the supporting ribs involved severe thermal stresses in addition to stresses due to internal and external pressure loads. A temperature gradient of approximately 800°F exists between the duct wall and the external skin. To provide the greatest resistance to wrinkling of the inner rib flange and duct skin the ribs and ducts were made of Rene' 41. The outer skin which operates at a much lower temperature than the duct (400°F) is in tension and is made of 301 half-hard stainless.

As noted above the ducts are an integral part of the blade from Station 90 outboard to the tip. The root section of the duct is supported from the hub by a gimbal and ball seal which allows flapping and lead-lag motion. In this region the duct material is 321 stainless. A sliding lip seal at Station 42 allows for expansion and feathering motion. Outboard of the lip seal the duct is supported by the blade structure and undergoes a transition from a single circular duct to the twin ducts of the constant blade section. In the transition region the duct material is Inconel "X," chosen because of the need for a material which is readily formable and weldable in the soft state that could be subsequently aged to obtain the higher strengths required.

Stainless steel (301-full hard) laminations (0.025 thick) made up in strap packs (2 straps per blade) attach the blade to the hub structure. Blade loads are transferred from the spars to the straps through attach fittings located between blade Stations 63 and 73. The straps, which wrap on shoes at either end, restrain the blade in the chordwise direction but allow freedom in coning and pitch. A feathering ball, attached to the blade root structure and mounted in a fabroid bearing in the hub, acts in conjunction with the straps in transferring shear loads from the blade to the hub.

FIGURE 5.2-1 HOT CYCLE ROTOR BLADE CONSTANT SECTION AREA

5.2.2 Spar Analysis (Reference Drawing 285-0170)

The hot cycle blade has two spars that are continuous from the inboard end, Station 19, to the tip, Station 330. The spars are machined from titanium (6 AL 4V) bar. The aft spar is shotpeened to increase its fatigue life.

The blade is so designed that all the flapwise bending is resisted by the spars. The remainder of the blade structure is made in segments that are connected by flexures. In addition to the flapwise bending loads, the spars also resist the centrifugal force loads, chordwise moment and an unbalanced duct pressure load. The spars are at elevated temperatures during operation. The temperature of the forward spar at Station 92 is 394°F and at Station 330 is 460°F. The temperature of the aft spar at Station 92 is 310°F and at Station 330 is 435°F.

The spar stiffness distribution was determined by the blade natural frequency requirements. Spar areas were adjusted to obtain satisfactory stress levels. The flapwise bending moment is distributed to the spars in a ratio of their moments of inertia. The blade is balanced about the 25% chord so that in the constant blade section, Station 74 to tip, the distribution of centrifugal force load is 57.5% to forward spar and 42.5% to aft spar.

A minor discrepancy exists in the stress analysis of the blade because:

(1) At the time of the analysis, the blade was balanced about the feathering axis and the C. F. load distribution to the spars was 55% to forward spar and 45% to the aft spar. (Should be 57.5% forward, 42.5% aft.)

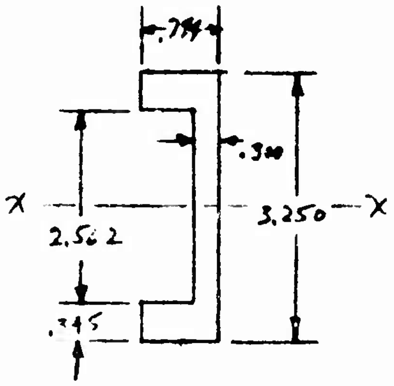
(2) The blade weight has increased over blade weight used in the analysis. The percent increase is

$$\left(\frac{425.7}{377 \times 1.05} - 1.0\right) 100 = 7.0\%.$$

Due to a failure of the rear spar during the Blade Fatigue Test, a steel doubler was added at Station 73. Analysis of the doubler installation is presented on Page 5.2.2.19.

SPAR SECTION PROPERTIES - REAR SPAR

STA. 61.7 TO STA. 75.30 (CONSTANT)

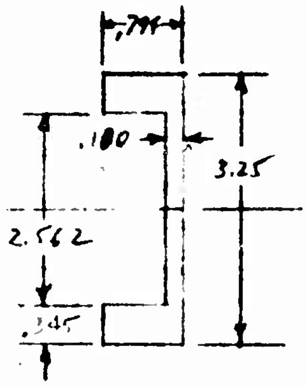


$$A = 3.25(.794) - 2.562(.494) = 1.32 \text{ in}^2$$

$$I_{xx} = \frac{.794(3.250)^3}{12} - \frac{.494(2.562)^3}{12}$$

$$= 2.260 - .692 = 1.568 \text{ in.}^4$$

STA. 24.25 TO STA. 58.70 (CONSTANT)



$$A = 3.25(.794) - 2.562(.614) = 1.01 \text{ in}^2$$

$$I_{xx} = \frac{.794(3.25)^3}{12} - \frac{.614(2.562)^3}{12}$$

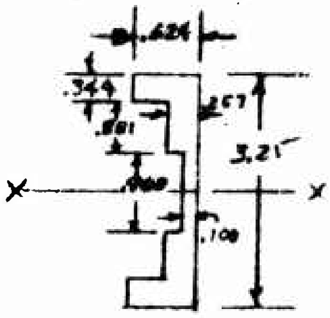
$$= 2.260 - .86 = 1.40 \text{ in}^4$$

$$\rho = \left[\frac{1.40}{1.01}\right]^{1/2} = 1.177 \text{ IN.}$$

SPAR ANALYSIS

SPAR SECTION PROPERTIES - REAR SPAR

STA. 78.30



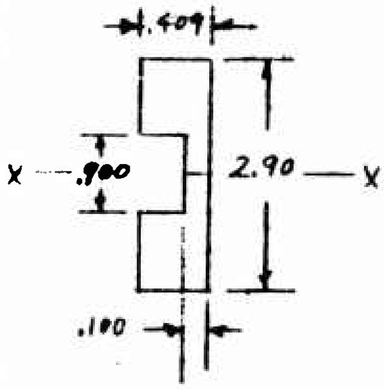
$$A = 3.25(.624) - 2.562(.367) - .900(.157)$$

$$= 2.025 - .940 - .141 = .944 \text{ IN.}^2$$

$$I_x = \frac{.624(3.25)^3}{12} - \frac{.367(2.562)^3}{12} - \frac{.157(.900)^3}{12}$$

$$= 1.780 - .514 - .009 = 1.26 \text{ IN.}^4$$

STA. 150

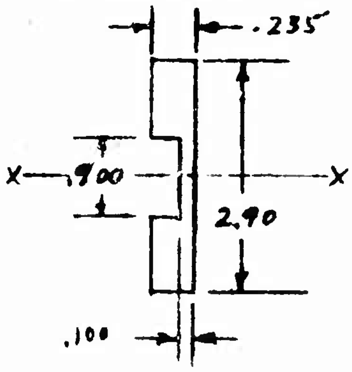


$$A = 2.90(.409) - .90(.309) = .922 \text{ IN.}^2$$

$$I_x = \frac{.409(2.90)^3}{12} - \frac{.309(.90)^3}{12} =$$

$$= .830 - .019 = .811 \text{ IN.}^4$$

STA. 225

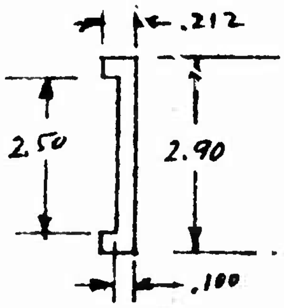


$$A = 2.90(.235) - .90(.135) = .560 \text{ IN.}^2$$

$$I_x = \frac{.235(2.90)^3}{12} - \frac{.135(.90)^3}{12}$$

$$= .478 - .008 = .470 \text{ IN.}^4$$

STA. 275



$$A = 2.90(.212) - 2.50(.112) = .324 \text{ IN.}^2$$

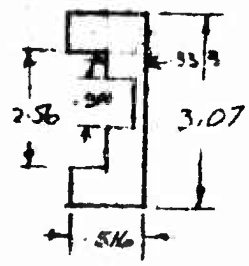
$$I_x = \frac{.212(2.90)^3}{12} - \frac{.112(2.50)^3}{12} =$$

$$= .431 - .146 = .285 \text{ IN.}^4$$

SPAR ANALYSIS

SPAR SECTION PROPERTIES REAR SPAR

STA 115



ADD .007 FOR EACH .10 FLUSH

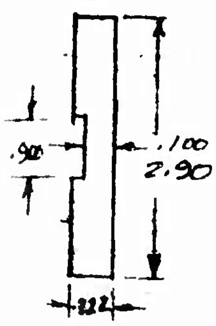
$A = 3.07(.516) - 2.56(.183) - .900(.233) + .014$

$= 1.584 - .468 - .210 + .014 = .920 \text{ IN}^2$

$I = \frac{.516(3.07)^3}{12} - \frac{.183(2.56)^3}{12} - \frac{.233(.9)^3}{12}$

$= 1.244 - .256 - .014 = .974 \text{ IN}^4$

STA 190

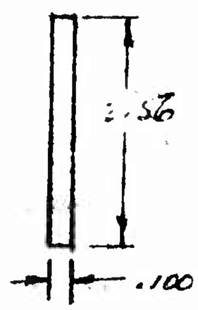


$A = .322 \times 2.90 - .900(.222) + .007 = .741 \text{ IN}^2$

$I = \frac{.322(2.90)^3}{12} - \frac{.222(.9)^3}{12} =$

$.658 - .013 = .640 \text{ IN}^4$

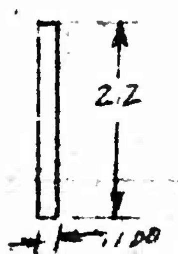
STA 300



$A = 2.56 \times .100 = .256 \text{ IN}^2$

$I = \frac{.100(2.56)^3}{12} = .140 \text{ IN}^4$

STA. 523.50

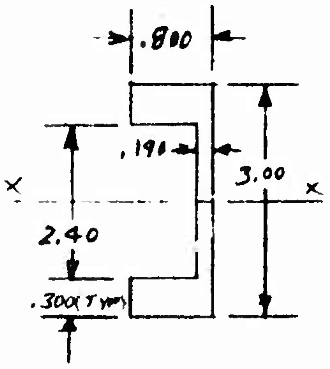


$A = .1 \times 2.2 = .220 \text{ IN}^2$

$I = \frac{.1 \times (2.2)^3}{12} = .089 \text{ IN}^4$

SPAR SECTION PROPERTIES - FRONT SPAR

STA. 24.25 TO 58.70 (CONSTANT)



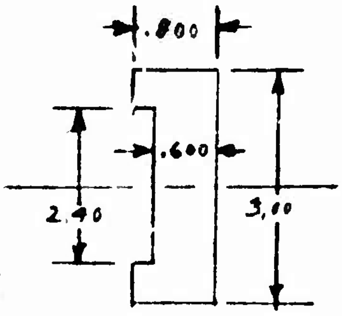
$$A = 3.00(.800) - 2.40(.610) = .936 \text{ in.}^2$$

$$I_{xx} = \frac{.800(3.00)^3}{12} - \frac{.610(2.40)^3}{12}$$

$$= 1.800 - .70 = 1.10 \text{ in.}^4$$

$$\rho = \left[\frac{1.10}{.936}\right]^{1/2} = 1.084$$

STA. 61.70 TO 74.00 (CONSTANT)

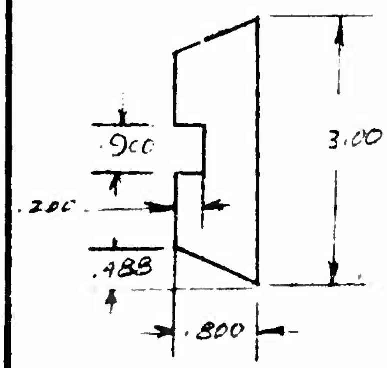


$$A = 3.00(.800) - 2.40(.20) = 1.92$$

$$I_{xx} = \frac{.800(3.00)^3}{12} - \frac{.200(2.40)^3}{12}$$

$$= 1.800 - .230 = 1.570 \text{ IN.}^4$$

STA 89.50



$$A = 3.00(.8) - .9(.2) - .488(\text{[illegible]}) + .014$$

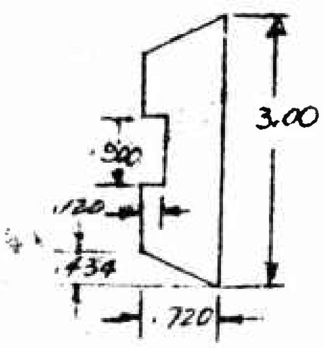
$$= 2.400 - .180 - .376 + .014 = 1.858$$

$$I = \frac{.8(3.00)^3}{12} - \frac{.2(.9)^3}{12} - .376(1.24)^2$$

$$= 1.800 - .012 - .675 = 1.113 \text{ IN}^4$$

SPAR SECTION PROPERTIES FRONT SPAR

STA 115



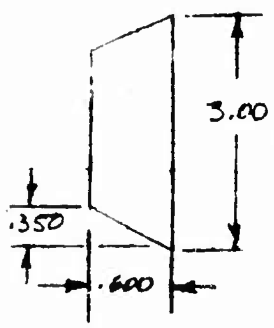
$A = 3 \times .720 - .434(.690) - .120(.90) + .014$

$= 2.160 - .299 - .108 + .014 = 1.767 \ IN^2$

$I = \frac{.720(3)^3}{12} - \frac{.120(.9)^3}{12} - .299(1.36)^2$

$= 1.620 - .007 - .553 = 1.060 \ IN^4$

STA 150



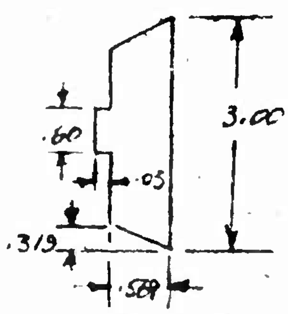
$A = 3.00 \times .6 - .350(.570)$

$= 1.800 - .200 = 1.600 \ IN^2$

$I = \frac{.6(3)^3}{12} - .200(1.38)^2 =$

$= 1.350 - .380 = .970 \ IN^4$

STA 190



$A = .569 \times 3 + .6 \times .03 - .319 \times .539 + .014$

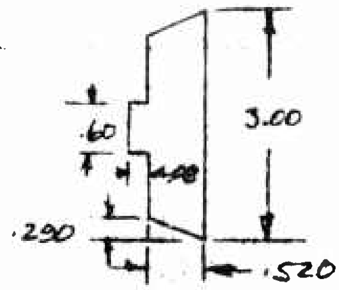
$= 1.707 + .019 - .172 + .014 = 1.568 \ IN^2$

$I = \frac{.569(3)^3}{12} - .172(1.392)^2 + \frac{.03(.60)^3}{12}$

$= 1.280 - .333 + 0 = .947 \ IN^4$

SPAR SECTION PROPERTIES FRONT SPAR

STA 225



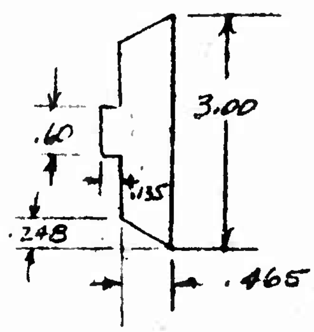
$$A = .520 \times 3 + .60 \times .08 + .014 - .290(.490)$$

$$= 1.560 + .048 + .014 - .142 = 1.480\ IN^2$$

$$I = \frac{.520(3)^3}{12} + \frac{.08(.6)^3}{12} - .142(1.403)^2$$

$$= 1.170 + .001 - .280 = .891\ IN^4$$

STA 275



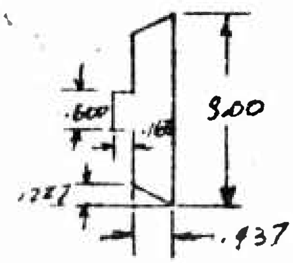
$$A = .465 \times 3. + .60 \times .135 + .014 - (.435)(.248)$$

$$= 1.395 + .081 + .014 - .108 = 1.382\ IN^2$$

$$I = \frac{.465(3)^3}{12} - \frac{.135(.6)^3}{12} - .108(1.418)^2$$

$$= 1.046 + .002 - .217 = .831\ IN^4$$

STA 300



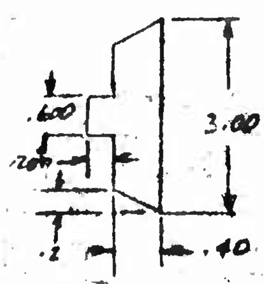
$$A = .437 \times 3.00 + .600 \times .163 - .407 \times .227$$

$$= 1.311 + .098 - .092 = 1.317\ IN^2$$

$$I = \frac{.437(3)^3}{12} + \frac{.163(.6)^3}{12} - .092(1.424)^2$$

$$= .983 + .003 - .186 = .800\ IN^4$$

STA 332.18

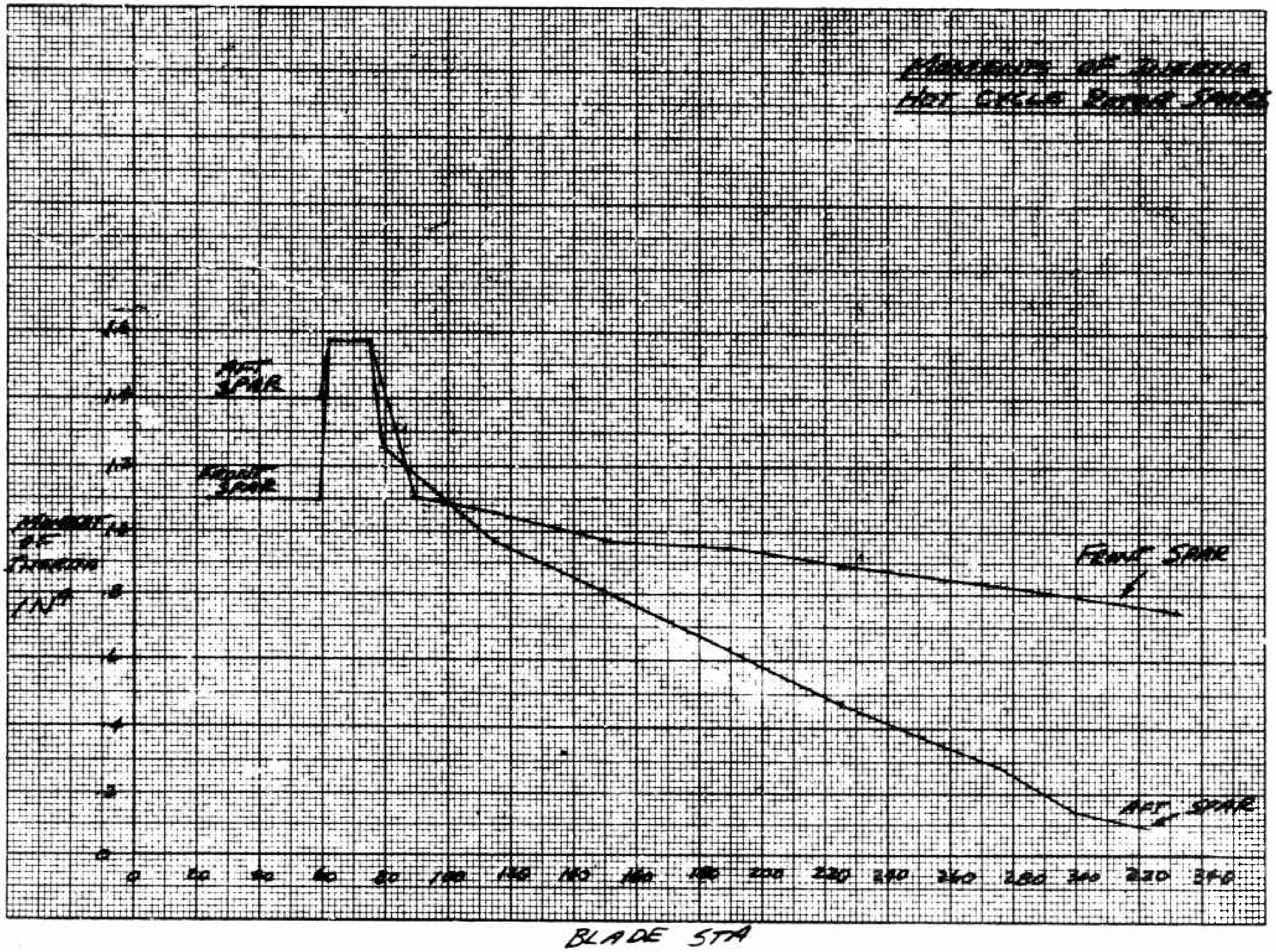


$$A = .40 \times 3.00 + .600 \times .200 - .370 \times .2$$

$$1.200 + .120 - .074 = 1.246\ IN^2$$

$$I = \frac{.400(3)^3}{12} + \frac{.200(.600)^3}{12} - .074(1.434)^2$$

$$= .900 + .004 - .149 = .755\ IN^4$$


MOMENTS OF INERTIA
HOT CYCLE ROTOR SPARS
MOMENT OF INERTIA IN^4
AFT SPAR
FRONT SPAR
FRONT SPAR
AFT SPAR
0 .2 .4 .6 .8 1.0 1.2 1.4 1.6
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340
BLADE STA

SPAR LOADS - WEIGHTED FATIGUE CONDITION

DISTANCE BETWEEN SPAR CENTROIDS IS 15.5 IN.

THE DISTANCE FROM THE CENTROID OF THE FRONT SPAR TO THE BLADE BALANCE AXIS IS 7.0 IN.

DISTRIBUTION OF CENTRIFUGAL FORCE:

FRONT SPAR = $\frac{8.5}{15.5}$ = 55 %

REAR SPAR = 45 %

STA	C.F (1)	C.F. FRONT SPAR	C.F. REAR SPAR	M_F CYCLIC	M_F (2) STEADY	M_C
60	-4725	-2600	-2125	±1600	2700	±15000
74	88200	48500	39700	±9500	2880	±62000
90	85050	46780	38270	±7400	3300	±54000
120	78750	43300	35450	±7000	4020	±43000
150	71400	39270	32130	±8300	4980	±34000
180	63000	34650	28350	±9600	5760	±24000
210	53025	29160	23865	±10200	6120	±16000
240	41475	22810	18665	±10000	6000	±10000
270	28875	15880	12995	±8000	4800	±5000
300	15750	8660	7090	±3700	2220	±1500
320	6300	3465	2835	± 900	540	± 500

NOTES: (1) CENTRIFUGAL FORCE HAS BEEN INCREASED 5% OVER PLOTTED VALUES (SECTION 4) TO ALLOW FOR BLADE WEIGHT INCREASE

(2) M_F (STEADY) = .60 (M_F CYCLIC) EXCEPT IN STRAP ATTACH AREA.

HUGHES TOOL COMPANY - AIRCRAFT DIVISION

ANALYSIS: Hot Cycle
PREPARED BY: D.W. Nichols 5-2-[illegible]
CHECKED BY:

MODEL: 285 REPORT NO. 285-13 PAGE 5.3.2.10

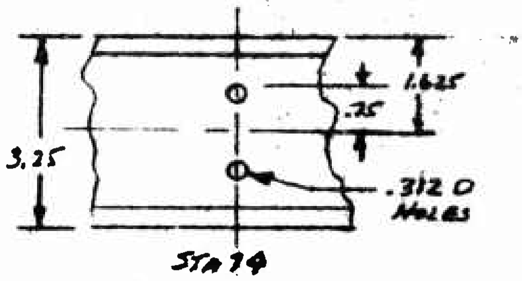
REAR SPAR WEIGHTED FATIGUE

STA	AREA	I_{TOTAL} IN^4	c	f_b * STEADY	C.F.	DUCT PRESS LOAD	f_{CF}	$f_{D.L.}$	$f_{T\ TOTAL}$	M_c	P_c	f_c CYCLE	f_b CYCLE	f_T CYCLE	F_c ALLOW	M.S.
60	1.81	2.66	1.62	-1640	-2135		-930		-3570	±15000	±1000	±310	±970	±[illegible]	±[illegible]	LARGE
74	1.32	3.14	1.62	1480	39700	1200	30980	910	32460	±62000	±4130	±3130	±4900	±8030	±[illegible]	1.37
90	.94	2.28	1.59	2300	38280	1200	40710	1280	44290	±54000	±3600	±3830	±5160	±8990	±[illegible]	[illegible]
120	.92	1.96	1.52	3120	36450	1200	38530	1300	42950	±43000	±2870	±3120	±5430	±8550	±[illegible]	.30
150	.82	1.78	1.45	4060	32130	1200	34920	1300	40280	±34000	±2270	±2490	±6760	±9230	±[illegible]	[illegible]
180	.81	1.62	1.45	5160	28350	1200	35000	1440	41640	±24000	±1600	±1975	±8590	±10590	±[illegible]	.66
210	.66	1.46	1.45	6080	23860	1200	36160	1820	44080	±16000	±1070	±1680	±10130	±11750	±[illegible]	.40
240	.50	1.38	1.45	6800	18660	1200	37330	2400	46530	±10000	±670	±1340	±[illegible]	±[illegible]	±15000	.18
270	.35	1.13	1.45	6160	13000	1200	37430	3430	46750	±5000	±330	±940	±[illegible]	±11210	±[illegible]	.30
300	.25	.98	1.27	3030	7090	1200	28360	4800	36190	±1500	±100	±400	±5050	±5450	±18100	LARGE
320	.22	.85	1.22	780	2830	1200	12890	5950	19120	±600	±33	±150	±1250	±1940	±21100	LARGE

* $f_{b\ STEADY}$ = .60 of $f_{b\ STATIC}$ EXCEPT IN STRAP ATTACH AREAS

REAR SPAR – WEIGHTED FATIGUE COND.

STA. 74 – SECTION AT SPAR TO RIB ATTACH



SPAR AREA = 1.32 IN.^{2}

I_{TOTAL} = 3.14 IN.^{4}

M_F (STEADY) = 4800 (.6) = 2880 IN. LBS.
C.F. (REAR SPAR) = 39,700 LBS.
DUCT PRESS. LOAD = 1200 LBS.
M_F (CYCLIC) = ± 9500 IN. LBS.
M_C (CYCLIC) = ± 62,000 IN. LBS.

AT BOLT HOLE

$$f_t \text{ (STEADY)} = \frac{39,700 + 1200}{1.32} + \frac{2880\,(.75)}{3.14} = 31,700 \text{ PSI}$$

$$f_F \text{ (CYCLIC)} = \frac{\pm 9500\,(.75)}{3.14} = \pm 2270 \text{ PSI}$$

$$f_C \text{ (CYCLIC)} = \frac{\pm 62,000}{15.5\,(1.32)} = \pm 3030 \text{ PSI}$$

$$f_{TOTAL} = 31,700 \pm 5300 \text{ PSI}$$

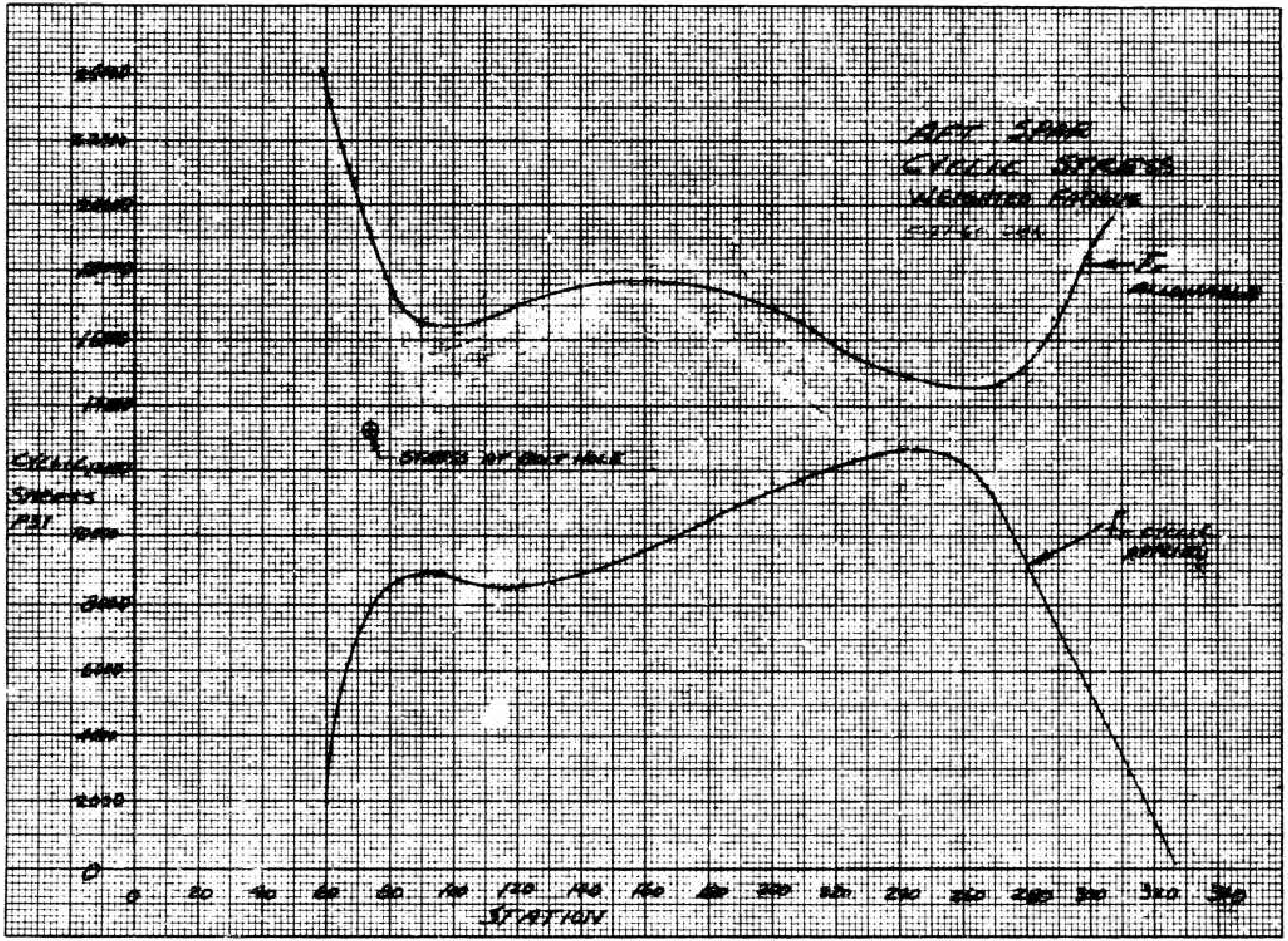
USE $a/W = \dfrac{.312}{1.50} = .208$

$K_t = 2.5$ (REF. PETERSON "STRESS CONC. DESIGN FACTORS")

$f_a = 2.5\,(\pm 5300) = \pm 13250$ PSI

$F_a = \pm 19,300$ PSI

$$M.S. = \frac{19300}{13250} - 1.0 = \underline{.45}$$


AFT SPAR
CYCLIC STRESS
STRESS AT BOLT HOLE
STATION
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340

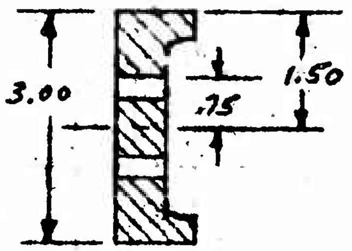
FRONT SPAR WEIGHTED FATIGUE

STA	AREA	$I_{N.A.}$	C_t	$f_{b\,STEADY}$*	CF	DUCT LOAD	$f_{C.F.}$	$f_{D.L.}$	$f_{T\,TOTAL}$	M/c	Pc	f_c CYCLE	f_b CYCLE	f_{TOTAL} CYCLE	F_{ALLOW}	M.S.
60	1.30	2.66	1.50	1520	27600	0	2000	0	-3520	±15000	±1000	±770	±900	±1670	±[illegible]	[illegible]
74	1.92	3.14	1.50	1370	48500	1200	25710	620	27250	±62000	±4130	±2150	±4540	±6690	±16590	1.47
90	1.86	2.28	1.50	2170	46780	1200	25250	650	27920	±54000	±3600	±1910	±4890	±6810	±16590	1.42
120	1.78	1.96	1.50	3080	43300	1200	24880	630	25,660	±43000	±2870	±1650	±5360	±7010	±16590	1.33
150	1.60	1.78	1.50	4200	39270	1200	[illegible]	750	[illegible]	±34000	±2270	±1420	±7000	±8420	±16300	.94
180	1.57	1.62	1.50	5330	34650	1200	22070	760	28160	±24000	±1600	±1020	±[illegible]	±9920	±11500	.66
210	1.52	1.46	1.50	6290	30160	1200	19180	790	26260	±16000	±1070	±700	±10480	±11180	±16700	.49
240	1.45	1.28	1.50	7230	22810	1200	15780	830	23500	±10000	±670	±460	±11720	±12180	±17000	.40
270	1.38	1.15	1.50	6370	15830	1200	11520	870	18750	±5000	±330	±290	±10620	±10850	±17700	.63
300	1.32	.93	1.50	3580	8660	1200	6560	910	11050	±1500	±100	±80	±5970	±6050	±18600	LARGE
320	1.28	.85	1.50	950	3460	1200	2710	940	4600	±500	±33	±30	±1590	±1620	±19500	LARGE

$* f_{b\,STEADY} = .60$ OF f_b CYCLIC EXCEPT IN STRAP ATTACH AREA

FRONT SPAR - WEIGHTED FATIGUE COND.

STA. 74 - SECTION AT SPAR ATTACH TO RIB



SPAR AREA = 1.92 IN.^{2}

I_{TOTAL} = 3.14 IN.^{4}

M_F (STEADY) = 2880 IN. LBS.
C.F. (FRONT SPAR) = 48,500 LBS.
DUCT PRESS. LOAD = 1200 LBS.
M_F (CYCLIC) = ±9500 IN. LBS.
M_C (CYCLIC) = ±62,000 IN. LBS.

AT BOLT HOLE

$f_t \text{ (STEADY)} = \dfrac{48{,}500 + 1200}{1.92} + \dfrac{2880(.75)}{3.14} = 26{,}600 \text{ PSI}$

$f_F \text{ (CYCLIC)} = \dfrac{\pm 9500\,(.75)}{3.14} = \pm 2270 \text{ PSI}$

$f_c \text{ (CYCLIC)} = \dfrac{\pm 62000}{15.5\,(1.92)} = \pm 2080 \text{ PSI}$

$f_{TOTAL} = 26{,}600 \pm 4350$

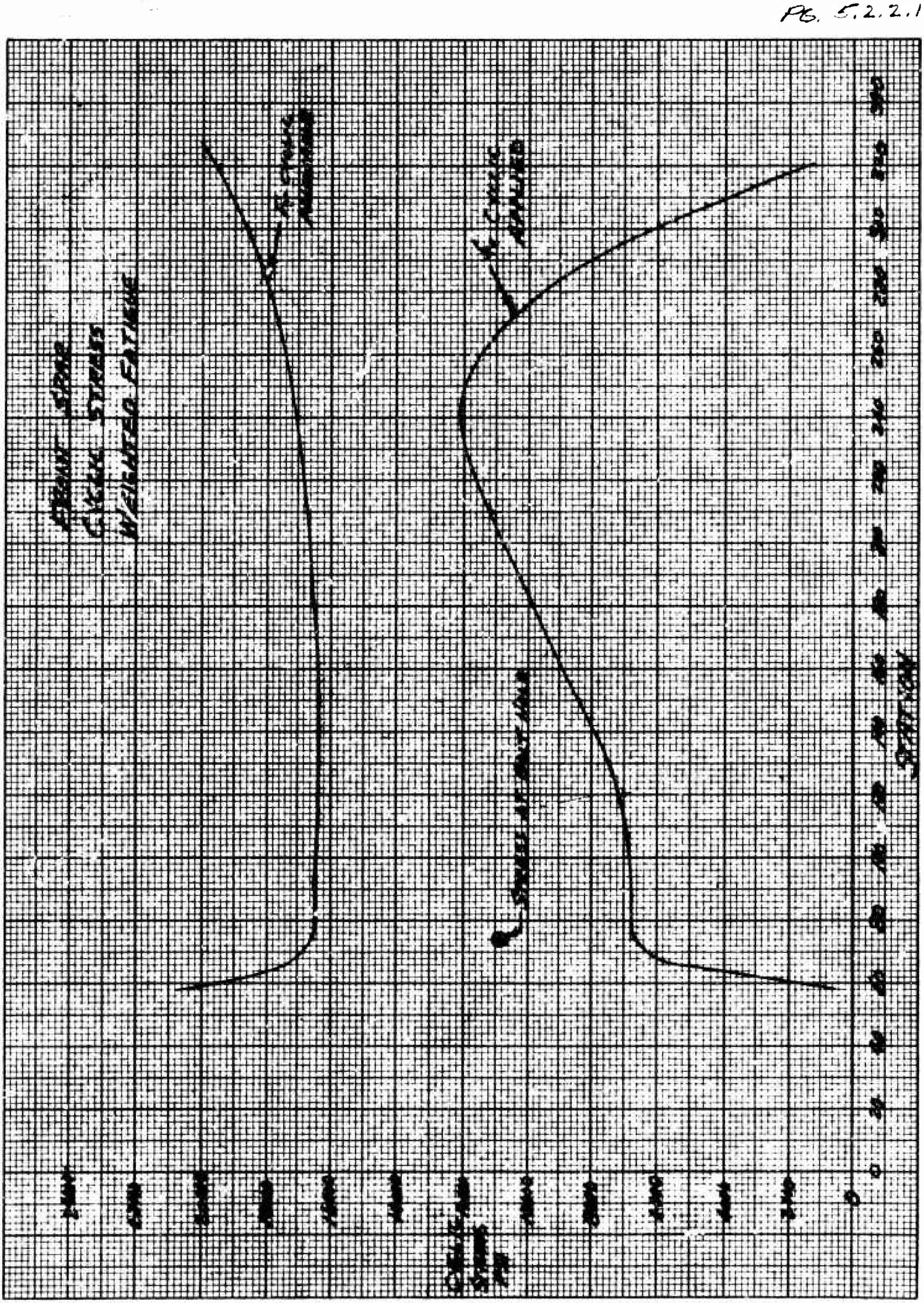
FOR $a/w = \dfrac{.312}{1.50} = .208$ $K_t = 2.5$ (REF PETERSON, "STRESS CONC. DESIGN FACTORS")

$f_a = 2.5\,(\pm 4350) = \pm 10{,}900$

$F_a = \pm 20{,}000$ PSI

$M.S. = \dfrac{20{,}000}{10{,}900} - 1.0 = \underline{\underline{.83}}$

PG. 5.2.2.15



FRONT SPAR
CYCLIC STRESS
WEIGHTED FATIGUE
STRESS AT MAX LOAD
STATION

REAR SPAR 2½G MANEUVER

MAX SPAR TEMP = 400°F
Ftu ROOM TEMP = 150,000
Ftu 400° = 150 × .81 = 121,500 PSI
911 MODEL 5

STA	A in²	I TOTAL	C	$f_{b.b.}$*	f_{CF}*	M.B. LB. STEADY + CYCLIC	f_b	MC	Pe	f_c	f_T	ftu	M.S.
60	4.01	2.66	1.62		-930	22300	13580	84000	5600	5090	19600	[illegible]	5.13
74	1.32	3.14	1.62	910	30070	23600	12170	206000	1230	10400	53550	80375	.51
90	.94	2.28	1.59	1280	40710	24700	17250	188000	12530	13330	72550	[illegible]	.12
120	.92	1.56	1.52	1300	38350	26500	20550	165000	11000	11960	72160	[illegible]	[illegible]
150	.92	1.78	1.45	1300	34920	28800	23460	142000	9470	10180	69860	[illegible]	.16
180	.81	1.62	1.45	1980	35000	29600	26490	118000	7870	9720	72690	[illegible]	.11
210	.66	1.46	1.45	1820	36160	28400	28210	95000	6330	9590	75780	113670	.07
240	.50	1.28	1.45	2900	37330	25500	28880	72000	4800	9600	78210	117320	.04
270	.35	1.13	1.45	3410	37130	19200	24640	49000	3270	9340	74540	111810	.03
300	.25	.93	1.27	4800	28360	8700	11880	26000	1730	6920	51960	77940	.66
320	.22	.85	1.22	5450	12890	800	1150	10000	670	3050	22540	33810	2.59
*	PG	21											

FRONT SPAR

2½ G MANEUVER

F_{TU} = 121,500 PSI @ 400°F

STA	A IN²	I TOTAL	C	$f_{J.P.}$*	$f_{C.F}$*	MB IN LB STEADY + CYCLIC	f_b	Mc	Pc	fc	f_T	f_{TU}	M.S.
60	1.30	2.66	1.50	0	-2000	22300	12540	84000	5600	4310	18850	28284	3.30
74	1.32	3.14	1.50	620	25260	23600	11270	206000	13730	7150	44300	66450	.83
90	1.86	2.28	1.50	650	25150	24700	16250	188000	12530	6740	48790	73190	.66
120	1.74	1.96	1.50	690	24890	26500	20280	165000	11000	6320	52180	78270	.55
150	1.60	1.78	1.50	750	24540	28800	24270	142000	9470	5320	54880	82320	.48
180	1.57	1.62	1.50	760	22070	29600	27400	118000	7870	5010	55240	82860	.47
210	1.52	1.46	1.50	790	19180	28400	29180	95000	6330	4160	53310	79970	.52
240	1.45	1.28	1.50	830	15730	25500	26380	72000	4800	3310	46250	69380	.75
270	1.38	1.13	1.50	870	11510	19200	25490	49000	3270	2370	40240	60340	1.01
300	1.32	.93	1.50	910	6560	8700	14030	26000	1730	1310	22810	34220	2.55
320	1.28	.85	1.50	940	2710	800	1410	10000	670	520	5580	8370	LARGE

* PG 5.2.2.13

HUGHES TOOL COMPANY - AIRCRAFT DIVISION

ANALYSIS: Hot Cycle
MODEL: 285
REPORT NO. 285-13
PAGE 5.2.2.18
PREPARED BY: D.W. Nicholls 5-31-60
CHECKED BY:

AFT SPAR FLAT PITCH OVER REV

$F_{TU} = 121{,}500$

STA	A IN^2	$f_{C.F.}$	$f_{D.L.}$	f_T	f_{TU}	M.S.
60	1.01	1450		1450	2175	LARGE
74	1.32	46980	910	47890	71840	.69
90	.94	63610	1280	64890	97340	.25
120	.92	59920	1300	61220	91830	.24
150	.92	54560	1300	55860	83790	.45
180	.81	54690	1480	56170	84260	.44
210	.66	56500	1820	58320	87480	.39
240	.50	58,330	2400	60730	91100	.33
270	.35	58,020	3430	61450	92180	.32
300	.25	44310	4800	49110	73670	.65
320	.22	20140	5450	25590	38390	2.16

FORM 8727

REAR SPAR "BEEF-UP"

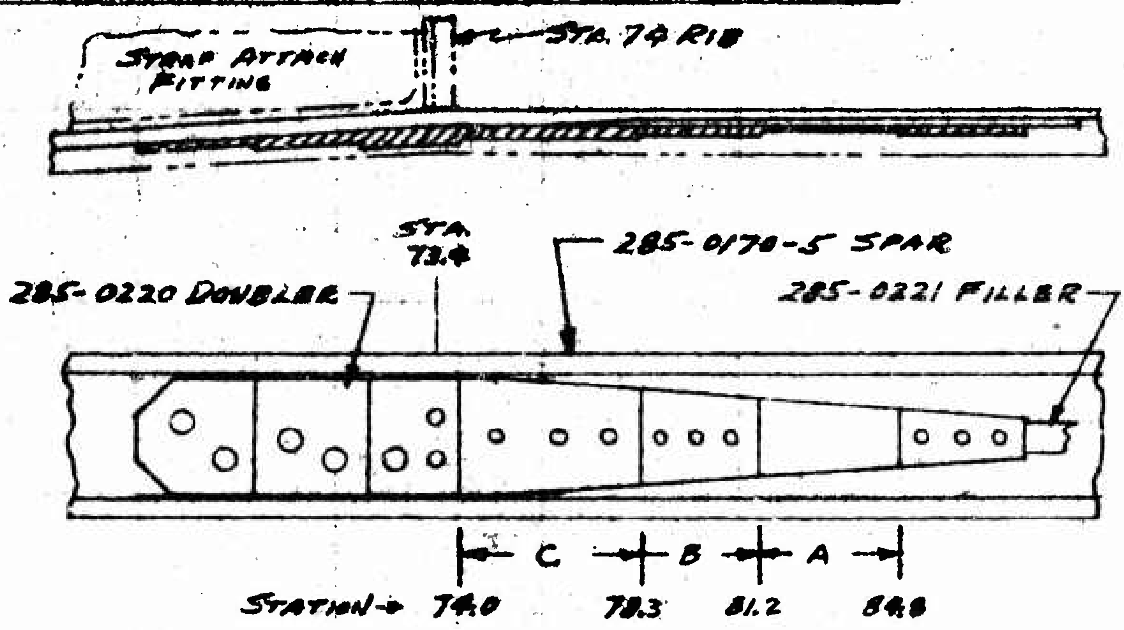
DOUBLER INSTAL.-REAR SPAR STA. 73 DWG. 285-0200

DURING THE BLADE FATIGUE TEST A FAILURE OCCURRED IN THE REAR SPAR AT BLADE STA. 73 THROUGH THE TWO BOLT HOLES USED TO ATTACH THE SPAR TO THE RIB AT THIS STATION. INSPECTION REVEALED THAT BURRS AND GALLING WERE PRESENT IN THE HOLES. ALTHOUGH THE FATIGUE FAILURE COULD BE LARGELY ATTRIBUTED TO THIS CONDITION IT WAS DECIDED, TO BE ON THE SAFE SIDE, TO ADD A DOUBLER TO THE WHIRL BLADE SPARS IN ADDITION TO A CAREFUL CLEANUP OF THE HOLES.

THE DOUBLER IS A STEP-MACHINED PLATE OF 4130 STEEL, HEAT-TREATED TO 160,000 PSI. IT NESTS AGAINST THE SPAR WEB, INSIDE THE FLANGES, AND EXTENDS FROM STA. 87.5 INBOARD TO STA. 66. LOAD IS PICKED UP IN THE DOUBLER BY SEVEN .25 IN. AND TWO .312 IN. BOLTS OUTBOARD OF STA. 73 AND TRANSFERRED OUT BY FIVE .50 IN. BOLTS WHICH ATTACH THE SPAR TO THE STRAP FITTING.

THE DOUBLER WAS ALSO INSTALLED ON THE FATIGUE TEST BLADE ALONG WITH A SPARE REAR SPAR. ADDITIONAL FATIGUE TESTING, SIMULATING THE LOADS AT STA. 73, GAVE STRUCTURAL SUBSTANTIATION OF THE DOUBLER INSTALLATION.

DOUBLER INSTAL. - REAR SPAR STA. 73



MATERIAL PROPERTIES:

SPAR - TITANIUM (6AL-4V)
$F_{TU} = 150,000$ PSI
$F_{TY} = 140,000$ PSI
$E = 16 \times 10^6$ PSI

DOUBLER - 4130 STEEL
$F_{TU} = 160,000$ PSI
$F_{TY} = 142,000$ PSI
$E = 29 \times 10^6$ PSI

LOAD DISTRIBUTION

DISTRIBUTION OF LOAD BETWEEN SPAR AND DOUBLER IS BASED ON THE EA OF THE MEMBERS. IN OBTAINING THIS DISTRIBUTION AVERAGE VALUES ARE USED FOR PROPERTIES IN SECTIONS A, B & C.

SECTION	DOUBLER PROPERTIES h	t	A_D	$A_{D(EFF)}$	A_{SPAR}	$A_{TOT.}$	% LD. DOUBLER
A	1.44	.08	.115	.208	.940	1.148	18 %
B	1.80	.15	.270	.490	.950	1.440	34 %
C	2.16	.25	.540	.980	1.14	2.120	46 %

DOUBLER INSTAL. (CONT'D.)

SECTION PROPERTIES

SECTIONS ARE CUT AT STATIONS 81.2, 78.3 AND 74.0

STA.	REAR SPAR			SPAR DOUBLER					I_{TOT} REAR	I FRONT	I BLADE
	h	I_S	A_S	h	t	A_D	I_D	$I_{D(EFF)}$			
81.2	3.23	1.23	.95	1.66	.08	.133	.0305	.055	1.285	1.37	2.65
78.3	3.24	1.26	.96	2.02	.15	.303	.103	.107	1.447	1.46	2.91
74.0	3.25	1.57	1.32	2.44	.25	.575*	.254*	.460	2.030	1.57	3.60

* CHAMFER TAKEN INTO ACCOUNT

WEIGHTED FATIGUE CONDITION

CENTRIF. FORCE (REAR SPAR) = 39,700 LBS.

DUCT PRESSURE LOAD = 1200 LBS.

$M_C = \pm 62,000$ IN. LBS.

$$P_{AXIAL} = 39,700 + 1200 \pm \frac{62,000}{15.5} = 40,900 \pm 4,000 \text{ LBS.}$$

$M_F = 2880 \pm 9500$ IN. LBS.

ALL LOADS CONSERVATIVELY ASSUMED CONSTANT THRUOUT DOUBLER REGION.

AXIAL STRESSES $P_A = 40,900 \pm 4000$ LBS.

STATION	% LD. SPAR	% LD. DOUB.	P_{SPAR}	$P_{DOUB.}$	A_{SPAR}	$A_{DOUB.}$	f_{AXIAL} SPAR	f_{AXIAL} DOUB.
81.2	82	18	33,500 ± 3280	7400 ± 720	.95	.133	35300 ± 3450	55500 ± 5400
78.3	66	34	27,000 ± 2640	13900 ± 1360	.96	.303	28200 ± 2750	46000 ± 4500
74.0	54	46	22,000 ± 2160	18900 ± 1840	1.32	.575	16700 ± 1640	32900 ± 3200

9704

DOUBLER INSTAL. (CONT'D)

BENDING STRESSES $M_F = 2880 \pm 9500$ IN. LBS.

STATION	I_{TOTAL}	$Y_{E.SPAR}$	$Y_{DOUB.}$	f_b (SPAR)	f_b^* (DOUB.)
81.2	2.65	1.615	.83	1750 ± 5800	1640 ± 5400
78.3	2.91	1.620	1.01	1600 ± 5300	1810 ± 5970
74.0	3.60	1.625	1.22	1300 ± 4300	1770 ± 5840
73.5 **	3.60	.75	.75	600 ± 1980	1090 ± 3590

NOTES: * $f_{b(DOUB.)} = \frac{MY}{I_{TOT.}}\left(\frac{29}{16}\right)$

** STRESSES SHOWN FOR STA. 73.5 ARE AT EDGE OF HOLE — BASED ON $t = .25$ IN.

TOTAL STRESSES

STA.	$f_{SPAR} = f_a + f_b$	$f_{DOUB.} = f_a + f_b$	SPAR (2)		DOUBLER (2)	
			F_a	M.S.	F_a	M.S.
81.2	37,050 ± 9250	57,140 ± 10,800	±18,500	.98	±17,500	.62
78.3	29,800 ± 8050	47,810 ± 10,470	±19,500	1.42	±19,800	.89
74.0	18,000 ± 5940	34,670 ± 9,040	±21,300	2.60	±22,500	1.49
73.5	17,300 ± 3620	22,600 ± 4520 (1)	±17,800	.97 (3)	±25,000	1.21 (3)

NOTES: (1) DOUBLER STRESSES AT HOLE ARE REDUCED TO ACCOUNT FOR LOCAL THICKNESS INCREASE TO .375

$f_{(DOUB)} = f_a + f_b\left(\frac{.25}{.375}\right)$

(2) FOR SPAR & DOUBLER ALLOWABLE CYCLIC STRESS SEE MAT'L. ALLOW. CURVES OF SECTION 2

(3) USE $K_t = 2.5$

DOUBLER INSTAL. (CONT'D.)

ATTACHMENT OF DOUBLER TO SPAR

FOR OVER-REV. CONDITION AT STA. 74

$P_{REAR\ SPAR}$ = 1.32(71840) = 94,800 LBS. ULT (REF. PG. 5.2.2.18)

46% OF LOAD IS IN DOUBLER

$P_{DOUBLER}$ = .46 (94,800) = 43,500 LBS. ULT.

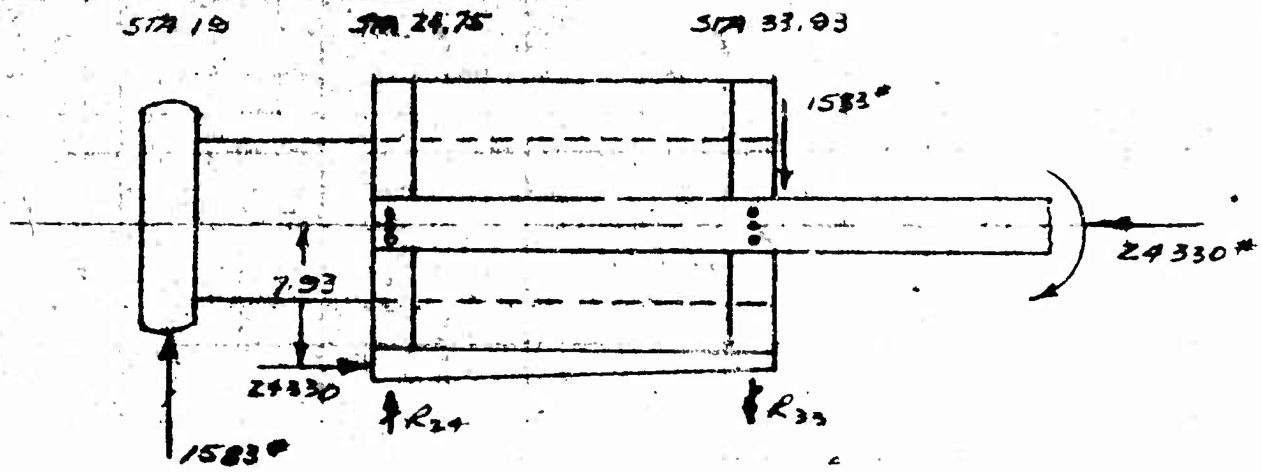
ATTACHMENT OF DOUBLER TO SPAR OUTB'D. OF STA. 74 CONSISTS OF SEVEN NAS 464 P4 AND TWO NAS 464 P5 BOLTS.

BOLT ALLOWABLES:

7 NAS 464 P4 BOLTS (SHEAR CRITICAL) = 7(4650) = 32,600
2 NAS 464 P5 BOLTS (SHEAR CRITICAL) = 2 (7300) = 14,600
TOTAL = 47,200 LBS.

$$M.S. = \frac{47,200}{43,500} - 1.0 = \underline{.08}$$

2½ G GROUND FLAPPING



REACTION AT FEATHERING BALL

$422.1 \times 2.5 \times 1.5 = 1583\#$ ULT

DROOP STOP LOAD.

BLADE WEIGHT 422.1 LBS (REF. SECTION 3)
C.G. LOCATION 140.9

$$\frac{422.1 \times 2.5 \times 1.5 \times 121.9}{7.93} = 24{,}330\# \text{ ULT}$$

$$\Sigma M_{33} = 1583 \times 14.93 + R_{24} \times 9.17 - 24330 \times 8.75$$

$$R_{24} = \frac{212{,}890 - 23630}{9.17} = 20{,}640\# \text{ ULT}$$

$$\Sigma Y_0 = 1583 + 20{,}640 - R_{33} - 1583 = 0$$

$$R_{33} = 20{,}640\# \text{ ULT.}$$

BENDING MOMENT OF BLADE AT STA 33.93

$M = 112{,}000 \times 1.5 = 168{,}000$ IN LBS ULT
(REF SECTION 4)

THE EFFECT OF THE BOLT HOLES WILL BE NEGLECTED IN CALCULATING THE BENDING STRESSES.

2½ G GROUND FLAPPING

$I_{STA\ 33.93} = 1.10 + 1.40 = 2.50\ IN^4$

$C = 1.625$

$$f_{bu} = \frac{168{,}000 \times 1.62}{2.50} = 109{,}200 \text{ PSI ULT.}$$

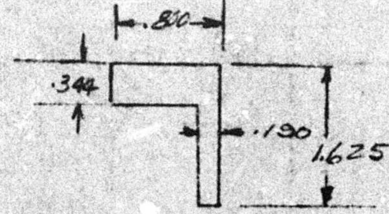
THERE IS ALSO A COMPRESSIVE LOAD WHICH MUST BE CONSIDERED.

AREA OF SPARS $= .94 + 1.02 - 6 \times .185 \times .75 = 1.68\ IN^2$

$$f_{cu} = \frac{24330}{1.68} = 14{,}480 \text{ PSI ULT}$$

$F_{cu} \cdot 146000$ PSI ROOM TEMP

$.77 \times 146{,}000 = 112{,}420$ 400°F.



$$K = \frac{2\,Q_m}{I/c}$$

$$K = \frac{2[(.8 \times .344 \times 1.281) + (.180 \times 1.281 \times .640)]}{1.40/1.65} = 1.27$$

$F_{bu} = 121{,}500 \times 1.27 = 154{,}300$

$$m_b = \frac{109{,}200}{154{,}300} = .71$$

$$m_t = \frac{14{,}480}{112{,}420} = .13$$

$$M.S. = \frac{1}{.71 + .13} - 1 = .19$$

BOLT BEARING STRESS ON SPAR, STA 33.93

ASSUMING THAT THE SHEAR DIVIDES EQUALLY AMONG THE BOLTS, THE NORMAL SHEAR IS:

$$\frac{24,330}{12} = 2,030 \text{ LBS ULT}$$

$$\frac{20,640}{6} = 3,440 \text{ LBS ULT}$$

RESULTANT SHEAR IS

$$\sqrt{11.83 \times 10^6 + 4.12 \times 10^6} = 3990 \text{ LBS ULT}$$

FALLOW NAS 144 = 4,650 LBS ROOM TEMP SINGLE SHEAR

.95 × 4,650 = 4420.

$$M.S. = \frac{4420}{3990} - 1 = \underline{.11}$$

BOLT BEARING AREA = .190 × .250 = .0475

$$f_{Br} = \frac{3990}{.0475} = 84,000 \text{ PSI}$$

F_{tu} @ 400° = 184,000 PSI

$$M.S. = \frac{184,000}{84,000} - 1 = \underline{1.19}$$

HUGHES TOOL COMPANY - AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE MODEL: 285 REPORT NO. 285-13 PAGE 5.2.2.27

PREPARED BY: D.W. NICHOLLS 6-1-60

CHECKED BY:

2½ G GROUND FLAPPING

AFT SPAR 2½ G GROUND FLAPPING CONDITION

STA	A	I TOTAL	C	MB IN LBS	fr	fcu	ftu	M.S.
60	1.01	2.66	1.62	59,000	54,200	10100	91400	.33
84	1.32	3.14	1.62	79000	40160	"	61,140	.99
90	.94	2.28	1.50	69000	48120	"	72180	.63
120	.92	1.96	1.52	53000	41100		61650	.97
150	.92	1.78	1.45	38000	30960	"	46440	1.62
180	.81	1.62	1.45	27000	24170	"	36260	2.35
210	.66	1.46	1.45	17000	16880	"	25320	3.80
240	.50	1.28	1.45	9000	10220	"	15300	LARGE
270	.35	1.13	1.45	5000	6420		9630	LARGE
300	.25	.93	1.27	2000	2730	"	5000	LARGE
330	.22	.85	1.22	500	720	"	1080	LARGE

FORM 9707

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS HOT CYCLE | MODEL 285 | REPORT NO. 285-13 | PAGE 5.2.2.28

PREPARED BY D.W. NICHOLLS 6-6-60

CHECKED BY

SPAR DEFLECTION
WEIGHTED FATIGUE

STA	MOMENT	I_A	I_F	M_A	M_F
25	550 IN LBS	1.40	1.10	308	242
30	1200			672	528
35	2200			1232	968
40	4500			2520	1980
45	6200			3472	2728
50	6850			3836	3014
55	7200	1.40	1.10	4032	3168
60	7400.	1.45	1.24	3996	3404
63	7450	1.57	1.57	3725	3725

MOMENT IS DIVIDED PROPORTIONING TO THE MOMENT OF INERTIA

STA	EI_A	EI_F	$\frac{M}{EI}_A$	$\frac{M}{EI}_F$
25	21.7×10^6	17.0×10^6	14.2×10^{-6}	14.2×10^{-6}
30	21.7×10^6	17.0×10^6	31.0×10^{-6}	31.0×10^{-6}
35	21.7×10^6	17.0×10^6	56.8×10^{-6}	56.8×10^{-6}
40	21.7×10^6	17.0×10^6	116.1×10^{-6}	116.1×10^{-6}
45	21.7×10^6	17.0×10^6	160.0×10^{-6}	160.0×10^{-6}
50	21.7×10^6	17.0×10^6	176.8×10^{-6}	176.8×10^{-6}
55	21.7×10^6	17.0×10^6	185.8×10^{-6}	185.8×10^{-6}
60	22.5×10^6	19.2×10^6	177.6×10^{-6}	177.6×10^{-6}
63	24.3×10^6		153.3×10^{-6}	

9704

ANALYSIS HOT CYCLE — MODEL 285 — REPORT NO. 285-13 — PAGE 5.2.2.29

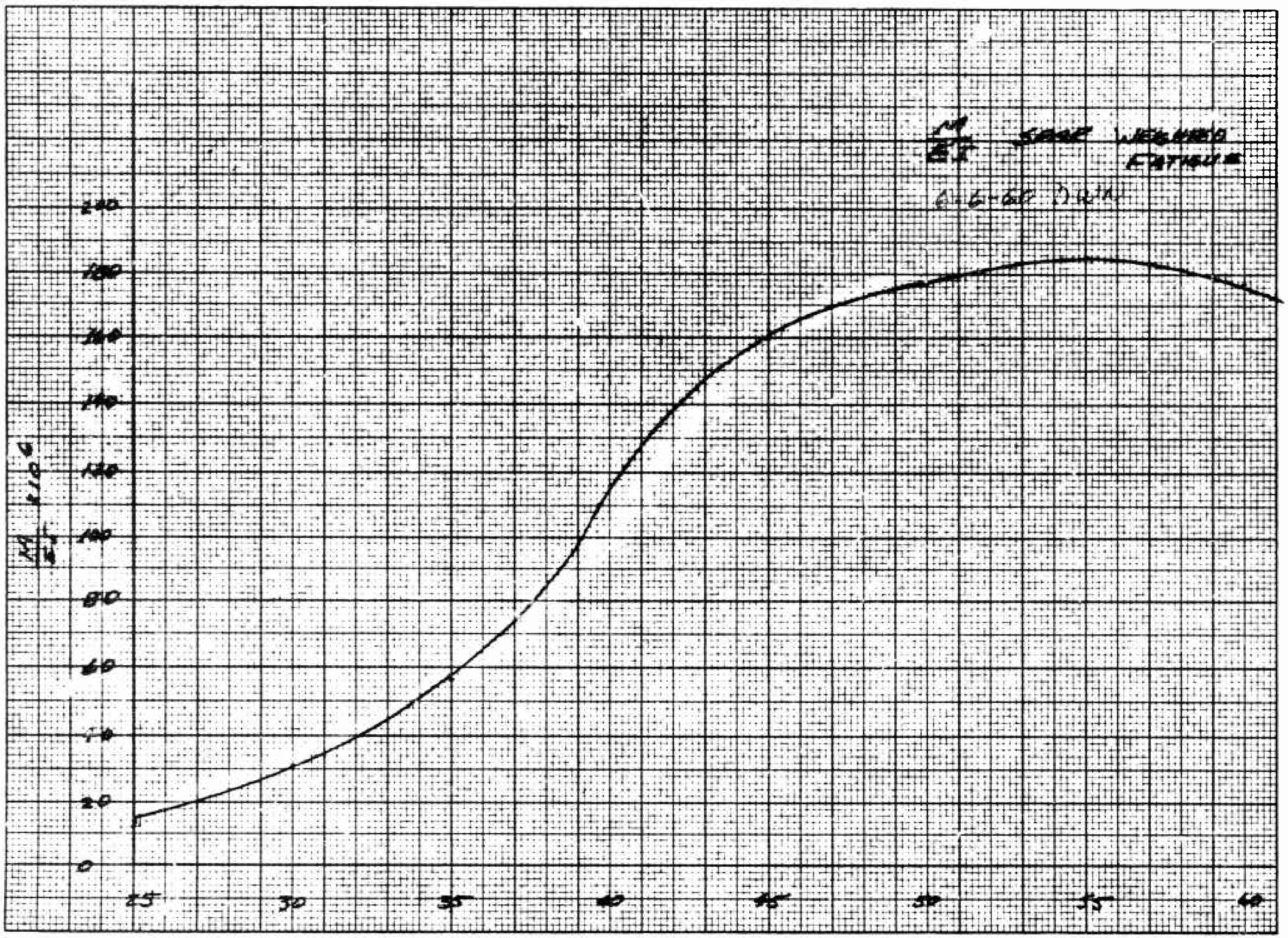
PREPARED BY D.W. NICHOLLS 6-7-60

CHECKED BY

SPAR DEFLECTION
WEIGHTED FATIGUE

STA	M/EI	M/EI AVE	ΔΘ	Θ	Θ AVE	ΔY	Y
19.90	0						
		7.1			21.5		
25	14.2		43	43		129	129 $\times 10^{-6}$
		18.1			65		
27.5	22.0		45	88		162	291
		26.5			121		
30	31.0		66	154		302	593
		36.5			200		
32.5	42.0		91	245		500	1093
		49.4			306		
35	56.8		123	368		765	1858
		67.9			453		
37.5	79.0		170	538		1132	2990
		97.5			660		
40	116.1		244	782		1650	4640
		129.5			944		
42.5	14.3		324	1106		2360	7000
		151.5			1295		
45	160		379	1485		3237	10237
		165.7			1692		
47.5	171.5		414	1899		4230	14467
		174.1			2116		
50	176.8		435	2334		5290	19757
		179.6			2558		
52.5	182.5		449	2783		6395	26152
		184.1			3013		
55	185.8		460	3243		7532	33684
		184.1			3973		
57.5	182.5		460	4703		9932	43616
		180.0			4428		
60	177.6		450	4153		11070	54686
		165.4			4401		
63	153.3		496	4647		11002	65688

9704


M/EI x10^6
240
180
160
140
120
100
80
60
40
20
0
25
30
35
40
45
50
55
60
6-6-60

FG. 5.2.2.30

HUGHES TOOL COMPANY – AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE

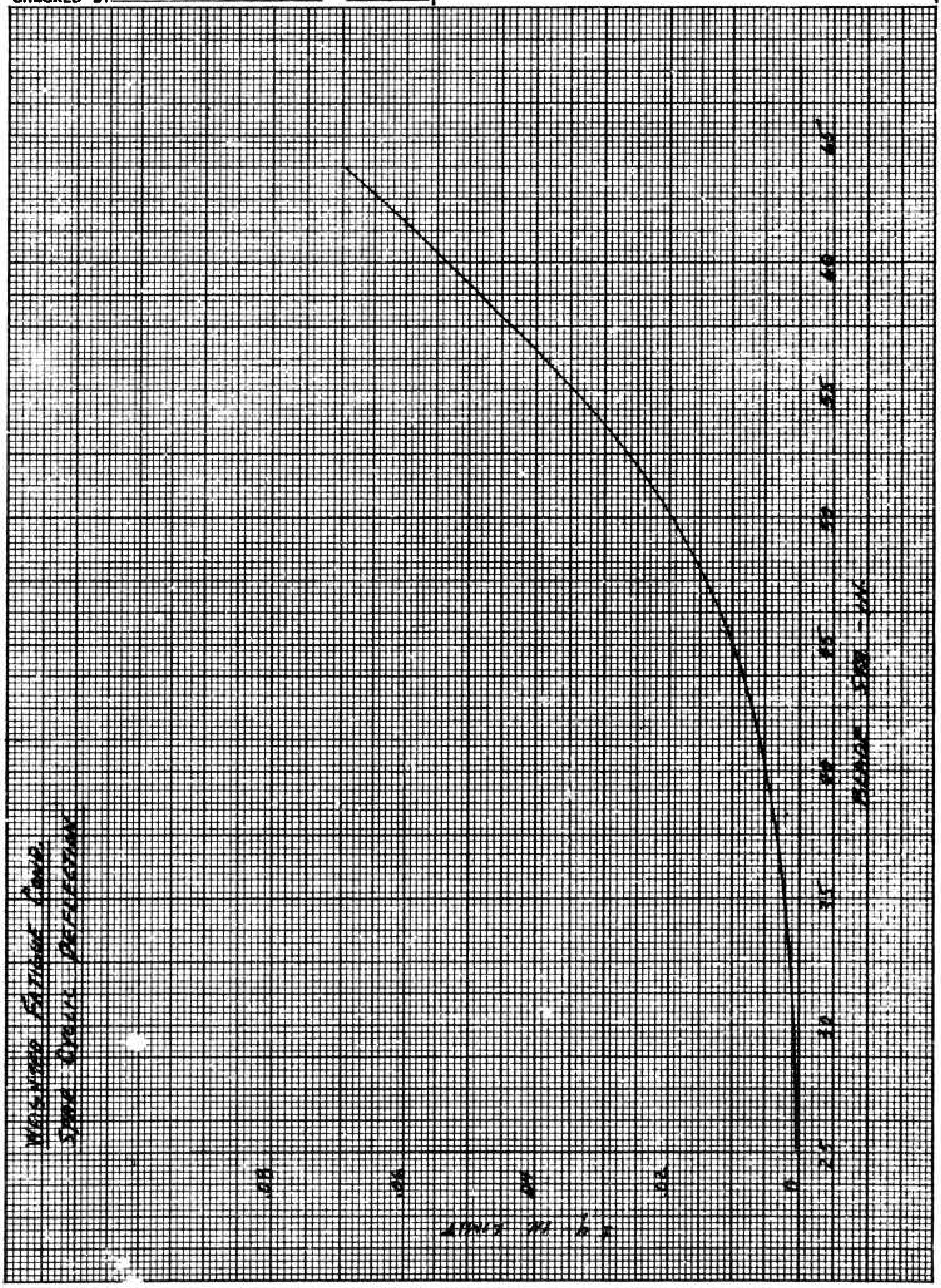
MODEL: 285

REPORT NO. 285-13

PAGE 5.2.2.31

PREPARED BY:

CHECKED BY:



ALBANENE NO. 195T

FORM NO. 9725

Deflection of Blade for 1g Loading (Blade Weight)

Deflection of the Blade between Sta. 19 and the Tip at Sta. 333

$$\delta_B = \frac{[illegible]}{15 \times [illegible]} = 38.9 \text{ in.}$$

Strap load for 1g loading with blade resting on droop stop.

$$P_{S_{avg.}} = \frac{56720}{2 \times 8.75} = 3250 \text{ lbs/strap}$$

Stretch of Strap

$$\Delta_S = \frac{PL}{AE} = \frac{3250(50)}{1.0 \times 26 \times 10^6} = .00625 \text{ in.}$$

Rotation at Sta 19 due to strap elongation

$$\Delta_S = .00625$$

$$\phi = \frac{.00625}{8.75} = .000715 \text{ rad.}$$

Deflection at tip (Sta 333) for rotation at Sta 19

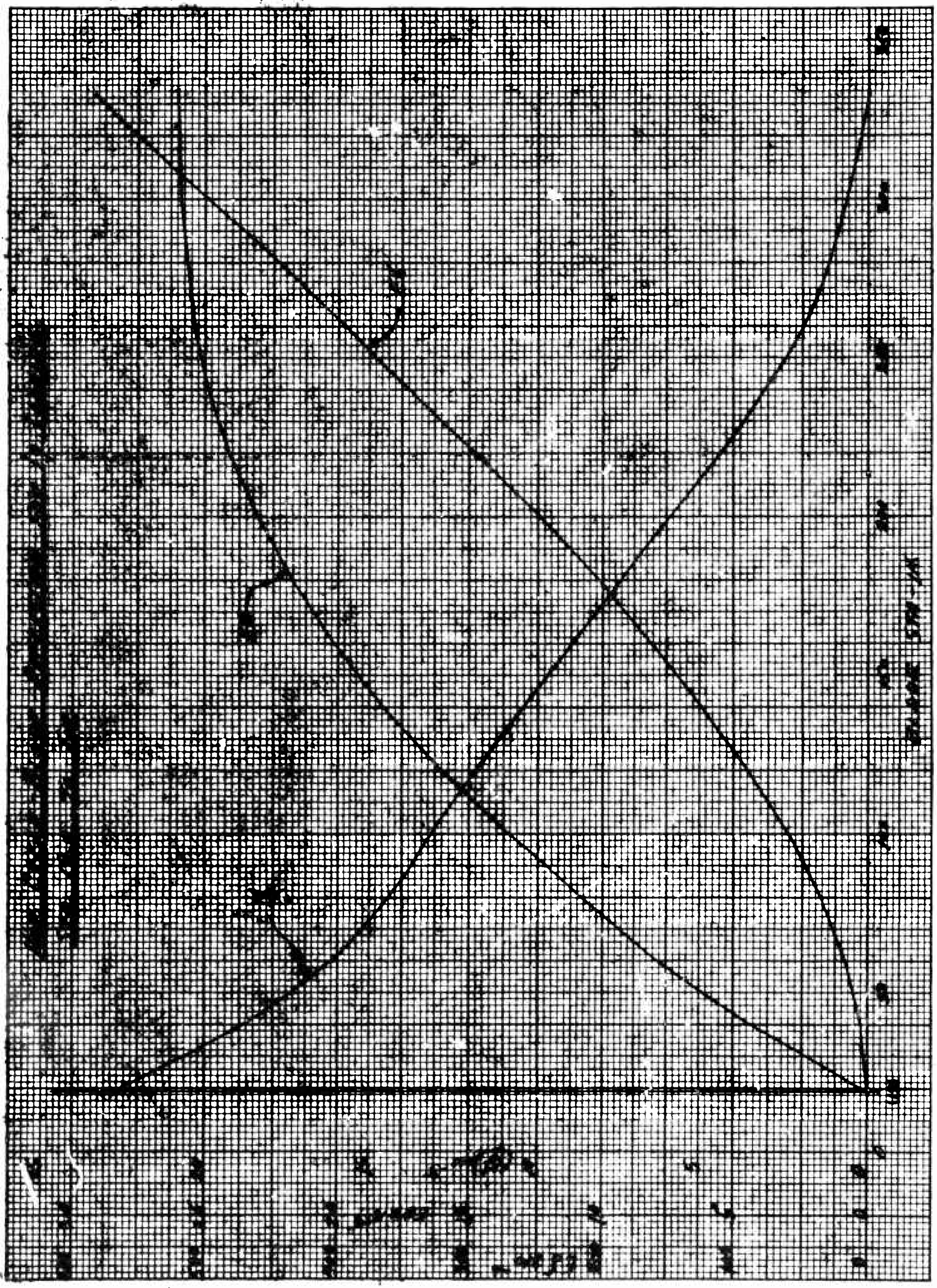
$$\delta_R = .000715(333-19) = .224 \text{ in.}$$

Deflection of tip for negative 2° coning angle

$$\delta_{CA} = 314\left(\frac{2.0}{57.3}\right) = 11.0 \text{ in.}$$

Total deflection of tip relative to hub at Sta. 19 for 1g loading

$$\delta_{TOT} = \delta_B + \delta_R + \delta_{CA} = 38.9 + .2 + 11.0 = \underline{50.1 \text{ in.}}$$



SECTION 5.2.3

BLADE RETENTION STRAPS

DWG 285-[illegible]121

INTRODUCTION

The primary purpose of the blade retention straps is to tie the blade to the hub while at the same time allowing freedom to cone and change pitch. The strap is attached to the hub at Sta. 15 and to the blade between Sta. 63 and 73. The strap is composed of 20 laminations of type 301 full hard corrosion resistant steel.

The stress in the strap is composed of four parts.

1. Axial tension stress due to centrifugal force and chordwise bending moment.
2. Peak bearing stress caused by the bending in the strap pack around the strap attach fittings.
3. Lamination bending stress due to the bending of the individual laminations to the radius of curvature of the attach fitting.
4. Torsion stress due to the strap twisting caused by changing the pitch of the blade.

The straps are subjected to [illegible] temperatures as follows

[illegible] 250°F

Station 60 350°F

Blade [illegible] 415°F

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS HOT CYCLE ROTOR
PREPARED BY D.W. NICHOLLS
CHECKED BY

BLADE RETENTION STRAPS

THE FOLLOWING ARE UNCORRECTED CHANGES IN THE ANALYSIS.

1. THE BLADE WAS BALANCED ABOUT THE 25% CHORD AND NOT THE FEATHERING AXIS AS SHOWN IN THE ANALYSIS. THIS CAUSES THE CENTRIFUGAL FORCE LOAD DISTRIBUTION TO BE 52% FRONT STRAP AND 48% AFT STRAP INSTEAD OF 50-50.

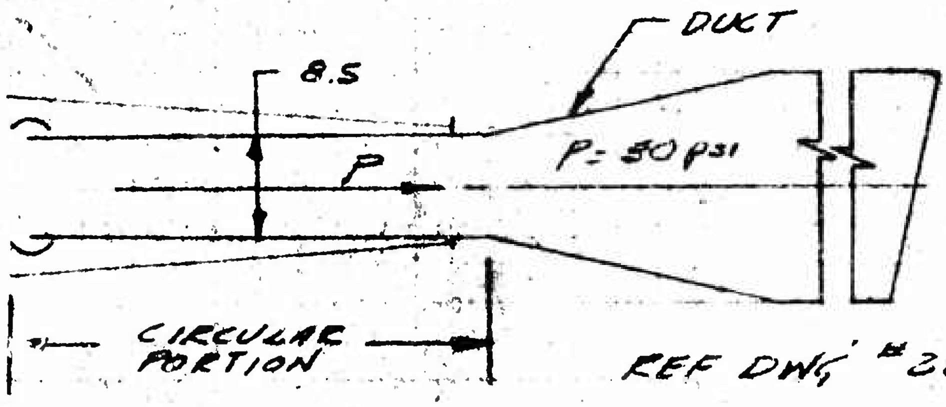
2. THE ACTUAL BLADE WEIGHT WAS ABOUT 10% HIGHER THAN THE PREDICTED BLADE WEIGHT.

3. THERE HAVE BEEN SOME SMALL CHANGES IN STRAP GEOMETRY AND PITCH ANGLES.

4. PARTIALLY REVISED STRAP LOADS HAVE BEEN COMPUTED ON PAGES 5.2.3.15 AND 5.2.3.16.

STRAP LOADS FROM DUCT PRESSURE

DUCT PRESSURE LOAD OUTB'D OF THE STRAPS.

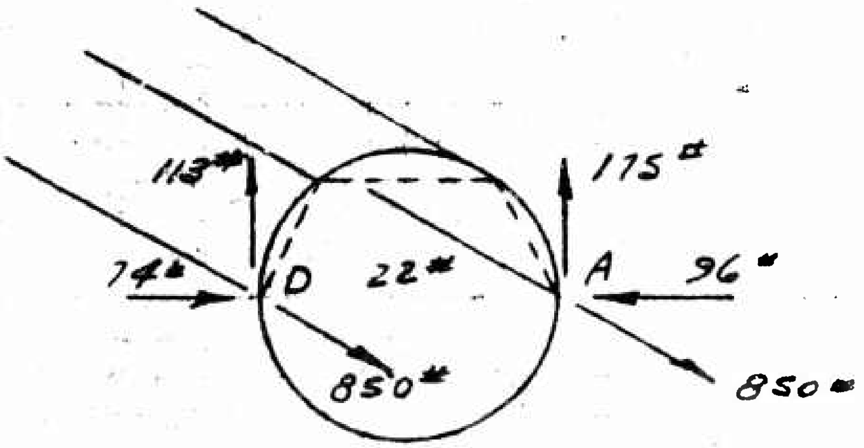


REF DWG #285-0111

PRES LOAD BASED ON THE CIRCULAR PORTION OF THE DUCT.

$$A = (8.5)^2 \frac{\pi}{4} = 56.6 \ IN^2$$

$$P = 56.6 (30) = 1700^{\#}$$



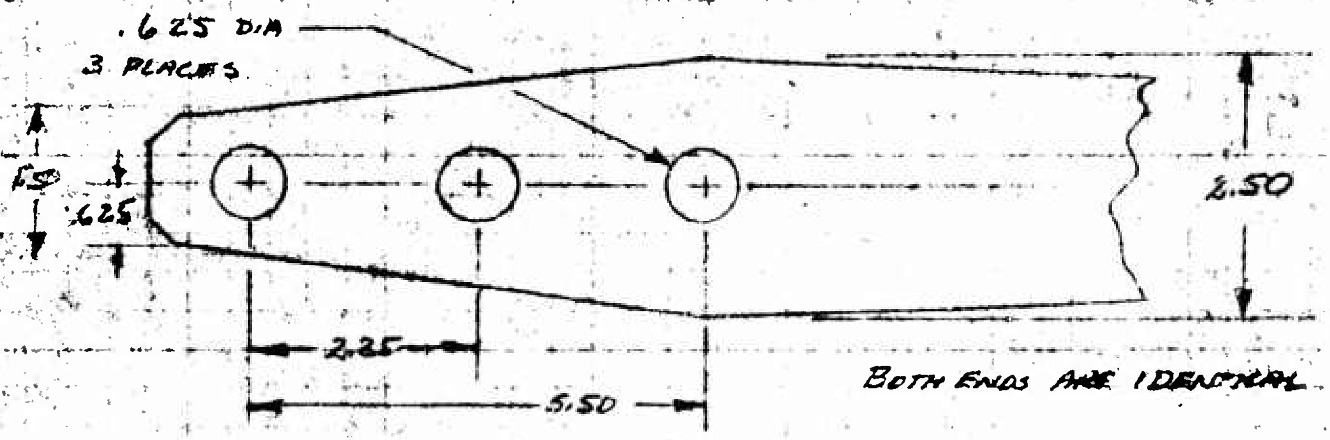
HUGHES TOOL COMPANY-AIRCRAFT DIVISION

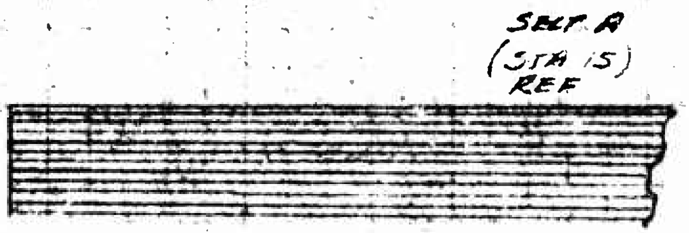
ANALYSIS: Hot Cycle
PREPARED BY: Bill Nicholls 12-4-53
CHECKED BY:
MODEL 285
REPORT NO. 285-13 PAGE 5.2.3.2

BLADE RETENTION STRAPS

STRAP LAYOUT DWG 285-0138
0121

STRAP GEOMETRY DWG 285-0121

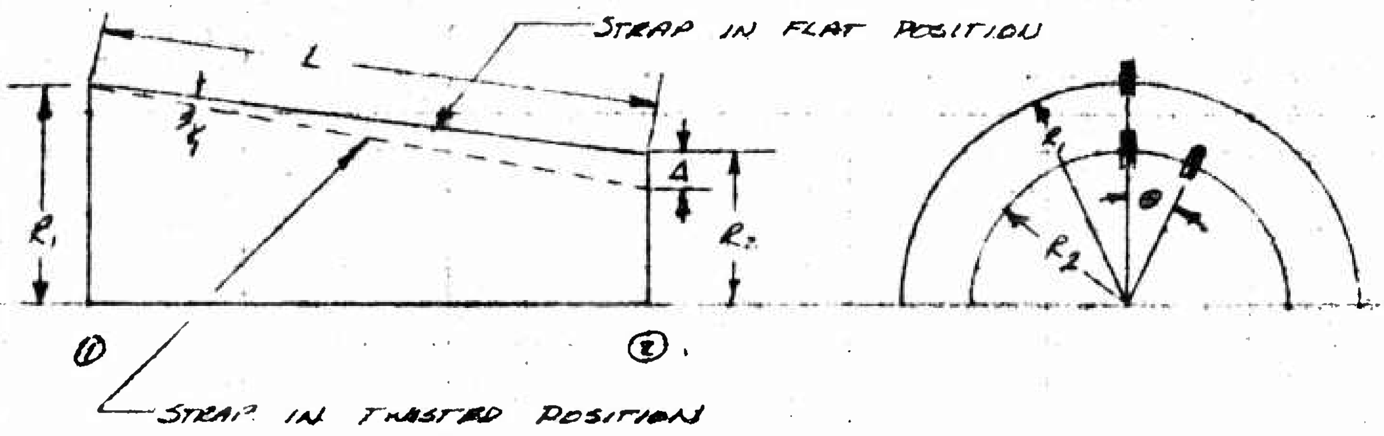




PACK IS COMPOSED OF 20 STRAPS OF .025 CORROSION RESISTANT STEEL TYPE 301 FULL HARD.

THE BENDING MOMENT IS LARGEST AT THE ENDS OF THE STRAPS THE STRESS IN THE STRAPS WILL THEN BE CALCULATED FOR THIS SECTION.

MOMENT DUE TO STRAP TWIST



$$\gamma_1 = \frac{R_2(1-\cos\theta)}{L}$$

$$\gamma_2 = \frac{R_1(1-\cos\theta)}{L}$$

$$P\gamma_1 = \frac{1}{j}\left[\frac{M_2 - M_1\cosh\frac{L}{j}}{\sinh\frac{L}{j}}\right] - \frac{1}{L}\left[M_1 - M_2\right]$$

$$P\gamma_2 = \frac{1}{j}\left[\frac{M_1 - M_2\cosh\frac{L}{j}}{\sin\frac{L}{j}}\right] + \frac{1}{L}\left[M_1 - M_2\right]$$

(REF C.C. BOSWELL & A. ROBERTSHAW 5-27-53)

WHERE $j = \sqrt{\frac{EI}{P}}$

P = AXIAL LOAD ON THE STRAP

FRONT STRAP

$R_1 = 10.6$

$R_2 = 5.2$

θ 2½G MANEUVER = 17.2°

θ WEIGHTED FATIGUE = 8.35°

θ FLAT PITCH OVERREV = 7.6°

Δ * P 2½G MAN = 63,200 LBS

Δ * P WTD FATIGUE = 51,450 ± 3820 LBS (LIMIT)

□ Δ * P FLAT PITCH OVERREV = 80,400 LBS (REF SECTION 4)

L = 49"

□ NO CHORDWISE MOMENT FORCE FOR OVERREV.

* LOADS ARE SAME FOR BOTH FRONT & REAR STRAPS

Δ INCLUDES 5% INCREASE FOR SPAR CHANGES & BALANCE
INCLUDES 1700# HMD DUCT PRESSURE LOADS.

STRAP MOMENT (CONT'D)

AFT STRAP
$R_1 = 10.6$
$R_2 = 6.5$

SOLVE FOR M_1 & M_2 2½ G MANEUVER. (FRONT STRAP)

$$\delta_1 = \frac{5.2(1-.95528)}{49} = .00475$$

$$\delta_2 = \frac{10.6(1-.95528)}{49} = .00967$$

SINCE THE BENDING MOMENT IS THE LARGEST AT THE END OF THE STRAP, THE SECTION PROPERTIES FOR SECTION A WILL BE CALCULATED

$$I = \frac{bh^3}{12} \qquad b = 20 \times .025 = .5$$

$$I = \frac{.5 \times (2.5)^3}{12} = .651 \text{ IN}^4$$

$$j = \sqrt{\frac{29 \times 10^6 \times .651}{6.32 \times 10^4}} = 17.29$$

$$(63,200)(.00475) = \frac{1}{17.29}\left[\frac{M_2 - M_1 \cosh\frac{49}{17.29}}{\sinh\frac{49}{17.29}}\right] - \frac{1}{49}\left[M_1 - M_2\right]$$

$$300 = .0578\left[\frac{M_2 - M_1(8.5022)}{8.4432}\right] - .0204\left[M_1 - M_2\right]$$

$$300 = .0578\left[.1184 M_2 - 1.0070 M_1\right] - .0204 M_1 + .0204 M_2$$

$$300 = .00684 M_2 - .0582 M_1 - .0204 M_1 + .0204 M_2$$

$$M_1 = .347 M_2 - 3820 \quad \text{IN LBS.}$$

$$(63,200)(.00967) = .0578\left[\frac{.347 M_2 - 3820 - M_2 \cosh 2.83}{\sin 2.83}\right] + .0204\left[.347 M_2 - 3820 - M_2\right]$$

STRAP MOMENT (CONT'D)

$$611 = .0598\left[-.9659 M_2 - 452\right] + .0204\left[-3820 - .653 M_2\right]$$

$$611 = -.0558\, M_2 - 26 - 78 - .0133\, M_2$$

$$M_2 = \frac{-715}{.0691} = -10{,}350 \quad \text{IN LBS.}$$

$$M_1 = .347(-10{,}350) - 3710 = -7300 \quad \text{IN LBS}$$

CONDITION	FRONT STRAP					AFT STRAP				
	δ_1	δ_2	j	M_1	M_2	δ_1	δ_2	j	M_1	M_2
2½ G MANEUVER	.00475	.00967	17.29	-7300	-10,350	.00593	.00967	17.29	-8520	-10,800
WEIGHTED* FATIGUE	.00112	.00229	18.47	-1600 ±90	-2200 ±120	.00141	.00229	18.47	-1825 ±100	-2290 ±130
FLAT PITCH OVER REV	.000932	.00190	15.33	-1560	-2260	.00116	.00190	15.33	-1790	-2320

* FOR THE WEIGHTED FATIGUE CONDITION THE CYCLIC MOMENT WILL BE ASSUMED TO BE THE SAME PERCENT OF THE STEADY MOMENT THAT THE CYCLIC AXIAL LOAD IS OF THE STEADY AXIAL LOAD.

STRAP STRESS

THE TOTAL STRESS IN THE STRAP IS COMPOSED OF 4 PARTS

1. TENSILE STRESS

$$f_1 = \frac{P}{A}$$ WHERE P = TENSILE LOAD
A = AREA OF STRAP AT SECT A
(SEE PAGE 1)

$$A = (2.5 - .625)(.5) = .937 \text{ IN}^2$$

STRAP STRESSES (CONT'D)

2. PACK BENDING

PACK BENDING STRESS IS CAUSED BY THE BENDING OF THE PACK AROUND THE SHOE.

$f_2 = \frac{Et\beta}{2L}$ WHERE β = ANGLE OF CONTACT
t = THICKNESS OF PACK
L = LENGTH OF STRAP

NOTE: THE EFFECT OF HUB SHOE TILT MUST BE TAKEN INTO ACCOUNT IN COMPUTING β.
β = CONING ANGLE + PITCH ANGLE + FLAPPING - SHOE TILT

3. LAMINATE BENDING

LAMINATE BENDING STRESS IS CAUSED BY BENDING THE INDIVIDUAL LAMINA TO THE RADIUS OF CURVATURE OF THE SHOE.

$f_3 = \frac{Et}{2R}$ t = THICKNESS OF EACH LAMINA
R = SHOE RADIUS OF CURVATURE

4. STRAP TWIST

STRESS DUE TO STRAP TWIST IS CAUSED BY THE BENDING MOMENT TABULATED ON PAGE 4.

$f_4 = \frac{M_z c}{I}$

MATERIAL PROPERTIES

ROOM TEMP 301 FULL HARD STAINLESS STEEL

ULTS 185,000 (REF 1)
YIELD 140,000

GEOMETRY

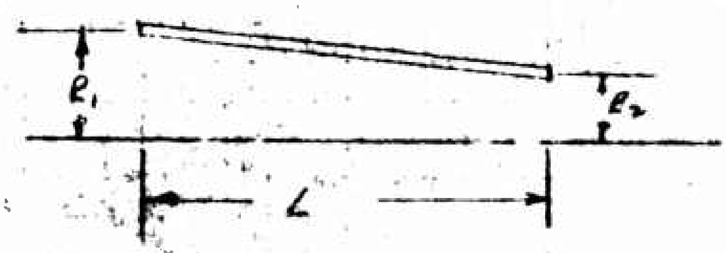
INBOARD { ϕ CONING ANGLE & FLAPPING ANGLE
{ θ ANGLE OF WRAP DUE TO PITCH CHANGE

OUTBOARD { α* BUILT IN STRAP WRAP
{ γ ANGLE OF WRAP DUE TO PITCH CHANGE

PITCH CHANGE AT CONTROL HORN

FLAT PITCH OVER REV.	$-7.6°$	REF SECTION 1
WEIGHTED FATIGUE	$0 \pm 8.35°$	
$2\frac{1}{2}$ G MANEUVER	$4.4 \pm 13.2°$	

THE AMOUNT OF WRAP DUE TO PITCH CHANGE IS A FUNCTION OF R, L, & PITCH CHANGE



$$\theta = \frac{\text{PITCH CHANGE} \times R_2}{L}$$

$$\gamma = \frac{\text{PITCH CHANGE} \times R_1}{L}$$

$R_1 = 10.6$

$R_2 = 5.2$ FRONT
$\quad\;\; 6.5$ AFT

$L = 49$ INCHES

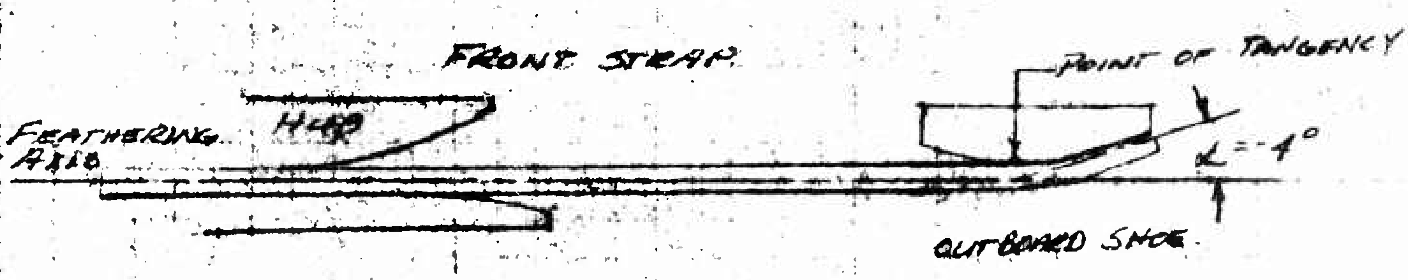
* FOR THE FRONT STRAP α DOES NOT INCLUDE NOMINAL SHOE WRAP OF 5°

GEOMETRY CONT'D

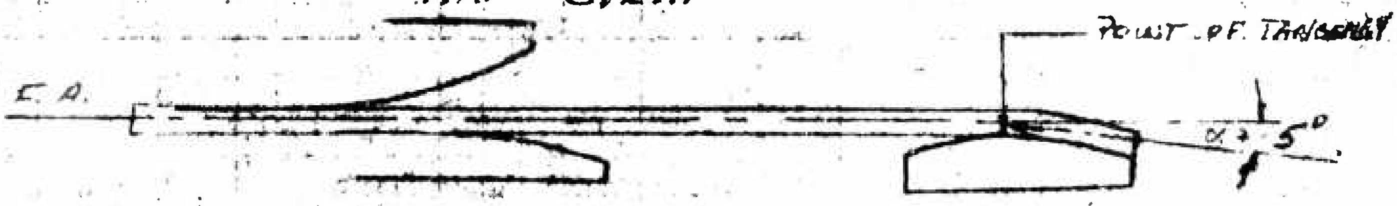
BASIC CONDITION 9° INITIAL CURVATURE IN FRONT STRAP

0° CONING, 7.6° COLLECTIVE PITCH.

FRONT STRAP



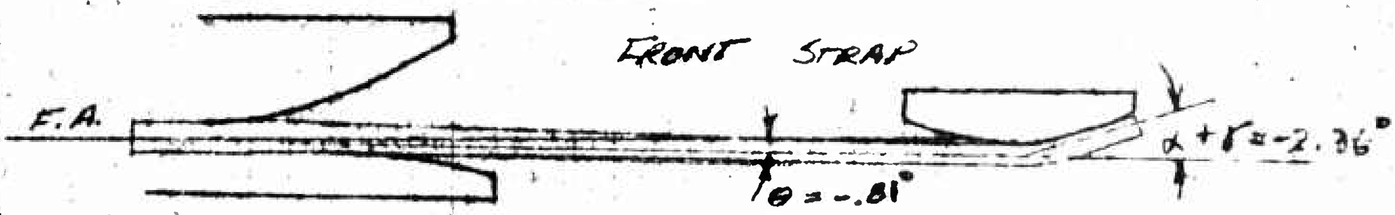
AFT STRAP



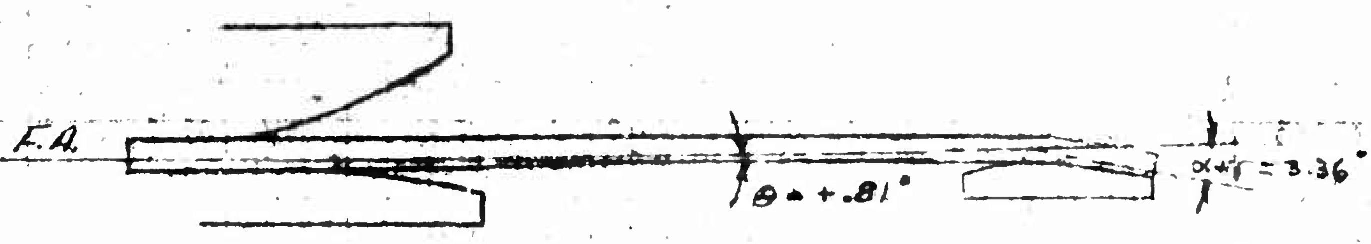
FOR 7.6° COLLECTIVE PITCH THE PLANE OF THE STRAPS CONTAINS THE FEATHERING AXIS AND THE POINTS OF TANGENCY ARE AT THE SAME STATION

FLAT PITCH OVER REV

FRONT STRAP



AFT STRAP



HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS: Hot Cycle

PREPARED BY: D.W. Nicholls 2-12-

CHECKED BY:

MODEL 285

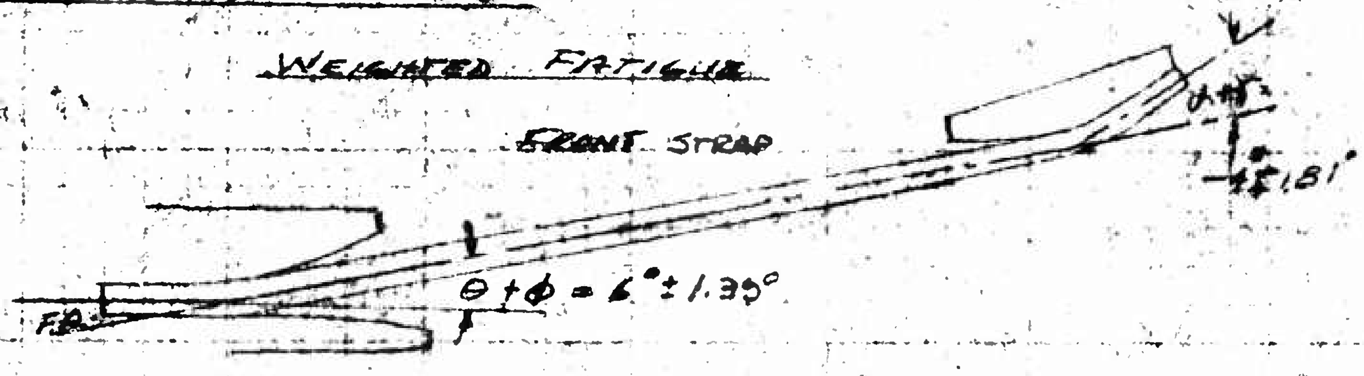
REPORT NO. 285-13

BLADE RETENTION STRAPS

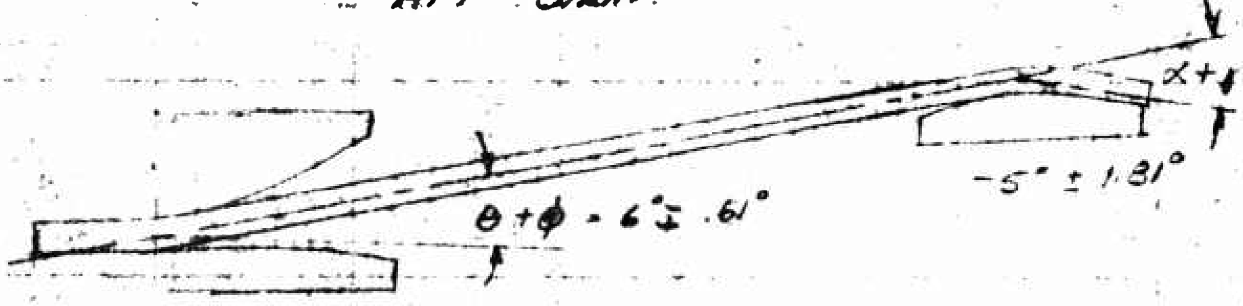
GEOMETRY. (CONT'D)

WEIGHTED FATIGUE

FRONT STRAP

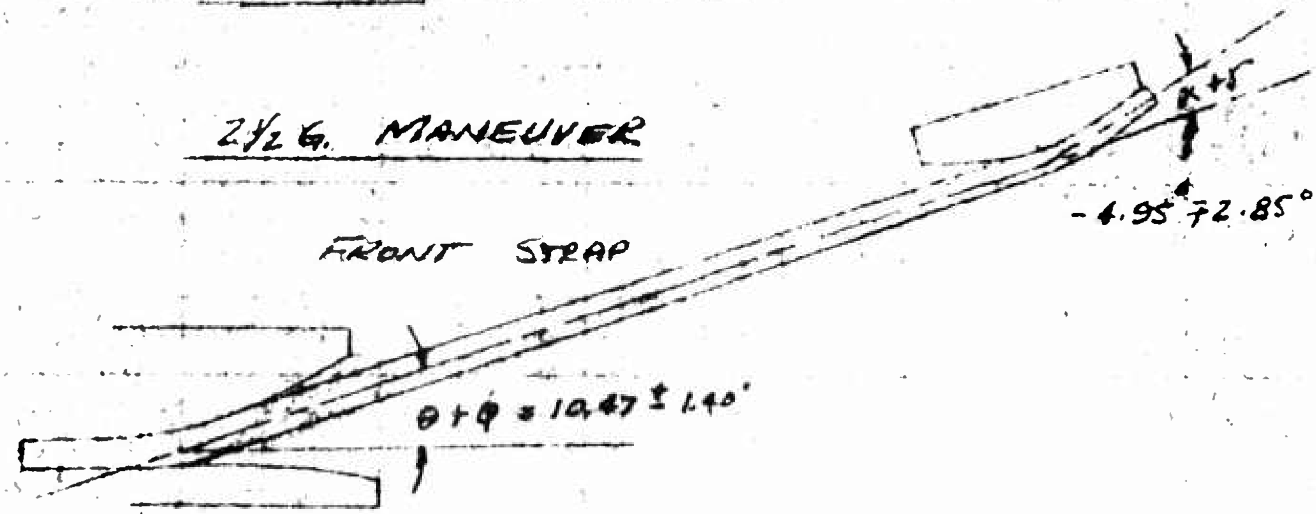


AFT STRAP

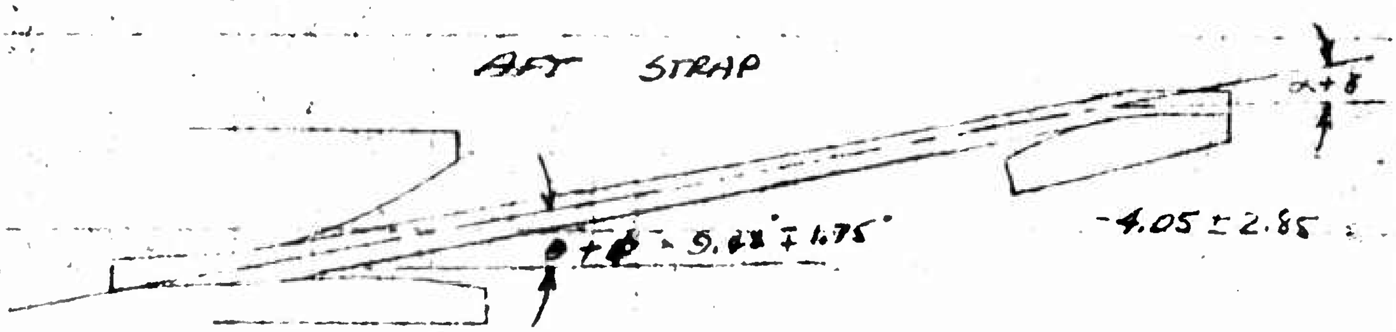


2½ G. MANEUVER

FRONT STRAP



AFT STRAP



HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS Hot Cycle MODEL 285 REPORT NO. 285-13 PAGE 5.2.3.10

PREPARED BY D.W. Nichaels 2-16-60

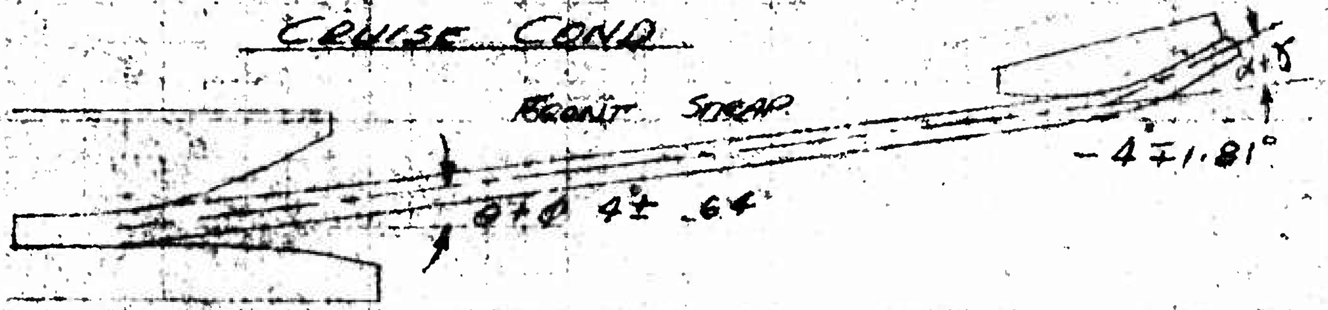
CHECKED BY

BLADE RETENTION STRAPS

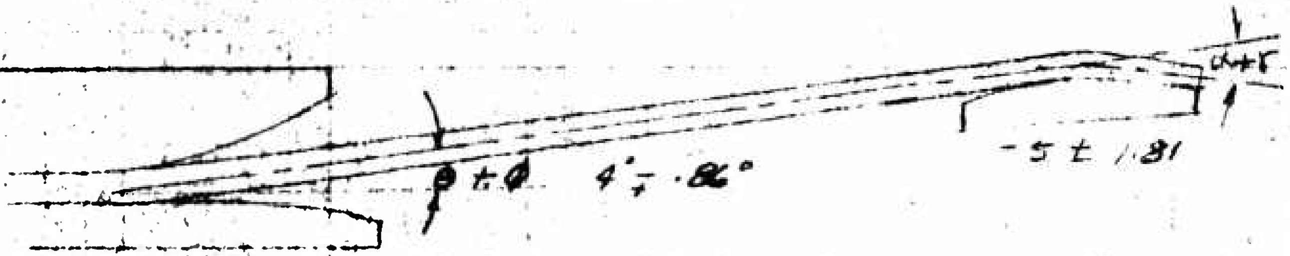
GEOMETRY (CONT'D)

CRUISE COND

FRONT STRAP



AFT STRAP



ANALYSIS: [illegible]
PREPARED BY: D. W. NICHOLLS 2-15-60
CHECKED BY:

BLADE RETENTION STRAPS

STRAP WRAP

CONDITION	PITCH CHANGE	STRAP	ϕ*	θ	TOTAL INBD	α	[illegible]	TOTAL OUTBD	NET [illegible] β
2½ G MANEUVER	4.4 ± 13.2°	FRONT	10°	.47° ± 1.40	10.47° ± 1.90°	-4°	-.85° ∓ 2.85	-4.95° ∓ 2.85°	5.52° ∓ 1.40
		AFT	10°	-.58° ± 1.75	9.42 ∓ 1.75°	5°	-.95° ± 2.85	4.05° ± 2.85°	6.53° ± 1.10
WEIGHTED FATIGUE	0 ± 8.35°	FRONT	6° ± .50	± .89°	6° ± .39	-4°	∓ 1.81°	-4° ∓ 1.81°	2° ∓ 1.42
		AFT	6° ± .50	± 1.11°	6° ∓ .61	-5°	± 1.81°	-5° ± 1.81°	1° ± 1.20
FLAT PITCH OVER-REV	-7.6°	FRONT	0	-.81°	-.81°	-4.0	+1.64°	-2.36	3.17°
		AFT	0	+.81°	+.81°	5°	-1.64°	+3.36°	4.17°
CRUISE	0 ± 8.35	FRONT	4° ± .25	± .89	4° ± .64	-4°	∓ 1.81°	-4 ∓ 1.81	0 ± 1.17°
		AFT	4° ± .25	∓ 1.11°	4° ∓ .56	-5°	± 1.81°	5 ± 1.81	-1° ± .95

* INCLUDES FLAPPING ANGLES WHERE APPLICABLE

STRESS SUMMARY

THE FOLLOWING STRESSES ARE BASED ON .500 MIN STRAP PACK THICKNESS, EXCLUDING BONDING. THERE IS ALSO 3° OF WEAR BUILT INTO THE FRONT STRAP.

TEMP AT INBOARD END 350°
TEMP AT OUTBOARD END 415°
} REF SECTION I

INBOARD END AT BOLT HOLE LIMIT LOADS
(NO LAMINATE BENDING)

CONDITION	P	CONING ANGLE	STRAP	M	β	f_1	f_2	f_3	f_4	f_{max}
2½G MANEUVER	93200	10°	FRONT	7300	6.92	67500	17900	0	14000	99400
			AFT	8520	7.63	67500	19700	0	16,400	103600
WEIGHTED FATIGUE	51450 ±3820	6°	FRONT	1600 ±90	2 ±1.42	54500 ±4000	5200 ±3700	0	3100 ±170	63200 ±7900
			AFT	1825 ±100	1 ±1.20	54900 ±4000	2600 ±3100	0	5000 ±190	62500 ±7300
CRUISE	51450 ±1900	4°	FRONT	1600 ±90	0 ±1.17	54900 ±2000	±3000	0	3100 ±170	58000 ±5200
			AFT	1825 ±100	1 ±.95	54900 ±2000	2600 ±2500	0	3500 ±190	61000 ±4700
FLAT PITCH OVERREV	80400	0°	FRONT	1560	3.17	85800	8200	0	3000	97000
			AFT	1790	4.17	85800	10,800	0	3440	100000

f_1 TENSILE STRESS

f_2 PACK BENDING STRESS

f_3 LAMINATE BENDING STRESS

f_4 BENDING STRESS DUE TO STRAP TWIST

BLADE RETENTION STRAPS

INBOARD END AT TANGENT POINT

AREA OF STRAP AT TANGENT POINT 1.178 in^2

CONDITION	P	CONING ANGLE	STRAP	M	β	f_1 C.F.	f_2 PITCH BEND	f_3 LAM. BEND	f_4 STRAP TWIST	f_{TOTAL}
2½ G MANEUVER	63200	10°	FRONT	7300	6.92	53650	17900	20100	15,900	107,550
			AFT	8520	7.63	53650	19700	20100	18400	111,850
WEIGHTED FATIGUE	51450 ±3820	6°	FRONT	1600 ±90	2 ±1.42	43700 ±3250	5200 ±3700	10,000 ±10100	2000 ±2200	60900 ±19250
			AFT	1825 ±100	1 ±1.20	43700 ±3250	2600 ±3100	10,000 ±10100	2000 ±2200	58300 ±18650
CRUISE	51450 ±1900	4°	FRONT	1600 ±90	0 ±1.17	43700 ±1600	±3000	10 000 ±10100	2000 ±2000	55700 ±16700
			AFT	1825 ±100	1 ±.95	43700 ±1600	2600 ±2500	10 000 ±10100	2000 ±2000	58,300 ±16200
FLAT PITCH OVER REV	80400	0°	FRONT	1560	3.17	68250	8200	20100	3400	100,000
			AFT	1790	4.17	68250	10800	20100	3900	103,100

IN THE EVENT THAT THE STRAP STIFFNESS MUST BE REDUCED 20% IT CAN BE ACCOMPLISHED BY REDUCING THE WIDTH OF THE STRAP 20%

THERE WILL BE NO LAMINATE BENDING STRESS IN THE CENTER OF THE STRAP SO

2½ G. f_T = 79,000 + 17900 + 18,400 = 115,300 psi

W. F. f_T = 64,200 ± 4780 + 5200 ± 3700 + 2000 ± 2200 = 71,500 ± 10,700 psi

F. P. f_T = 100,500 + 8200 + 3400 = 112,100 psi

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE — MODEL 285 — REPORT NO. 285-13 — PAGE 5.2.3.H

PREPARED BY: D.W. NICHOLLS 3-7-50 — BLADE RETENTION STRAPS

CHECKED BY:

OUTBOARD STRAP END AT TANGENT POINT

$I = .545$ $\quad W = 2.356$ (LIMIT STRESSES)

CONDITION	P	CONING ANGLE	STRAP	M	β	f_1	f_2	f_3	f_4	f_{TOTAL}
2½ G MANEUVER	63200	10°	FRONT	10,350	6.92	53650	17900	20100	22,350	114,000
			AFT	10,800	7.63	53650	19700	20100	23,330	116,782
WEIGHTED FATIGUE	51450 ±3820		FRONT	2200 ±120	2 ±1.92	43700 ±3250	5200 ±3700	10,000 ±10,100	4750 ±260	63,650 ±17,300
			AFT	2290 ±130	1 ±1.20	43700 ±3250	2600 ±3100	10,000 ±10,100	4950 ±280	61,250 ±16,730
CRUISE	51450 ±1900		FRONT	2200 ±120	0 ±1.17	43700 ±1600	±3000	10,000 ±10100	4750 ±260	58,450 ±15000
			AFT	2290 ±130	1 ±.95	43700 ±1600	2600 ±2500	10,000 ±10,100	4950 ±280	61,250 ±[illegible]
FLAT PITCH OVER REV	80[illegible]		FRONT	2260	3.17	68250	8200	20100	4890	101,500
			AFT	2320	4.17	68250	10000	20100	5000	104,150

FOR MATERIAL STRESS RELIEVED 8 HR AT 800°F RC445 .020 SHT.

$F_{tu} = 185,000$ PSI $\qquad$ AT 415° = 174,000 PSI REDUCED 6% MIL HDBK 5

$F_{ty} = 140,000$ PSI

BENDING MODULUS OF RUPTURE APPLIES TO f_3 & f_4

$$R_b = \frac{43,400 \times 1.5}{174,000 \times 1.5} = .25$$

$$R_t = \frac{73,400 \times 1.5}{174,000} = .635 \qquad M.S. = \frac{1}{.25 + .635} - 1 = .13$$

BLADE RETENTION STRAPS

REVISED STRAP LOADS FOR REVISED BLADE WEIGHT AND BLADE BALANCE AT 25% CHORD.

REVISED BLADE WEIGHT LESS STRAPS & INBOARD DUCT

$WT = 429.7^{\#}$ C.G. @ 148.8 IN.

$C.F. = 1.645 \times 429.7 \times 148.8 = 105200^{\#}$ (NORMAL FLIGHT) 700 FPS

FROM PG. 3 OF SECTION (STRUCTURE 33 TO 03)

$$\left.\begin{aligned} A_F &= .5201\,(105200) = 54700^{\#} \\ A_A &= .4799\,(105200) = 50500^{\#} \\ S_{15} &= .01443\,(105200) = 1520^{\#} = -S_{19} \end{aligned}\right\} \text{(REF 5.2.8.2, .3)}$$

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

MODEL 285 REPORT NO. 285-13 PAGE 5.2.3.16

ANALYSIS HOT CYCLE
PREPARED BY J. NEEDHAM 9-21-60
CHECKED BY

BLADE RETENTION STRAPS

2½ G MANEUVER CONDITION

CHORDWISE SHEAR & BENDING MOMENT
(OUTBOARD STRAP END)

@ STA 74 $S = 100 \pm 1500$ $M = \pm 163{,}000''^{\#}$

$A = .04971(\pm 163000) + 2.628(100 \pm 1500) = 11140^{\#}$
LIM MAX

COMBINED CENTRIFUGAL FORCE AND CHORDWISE SHEAR LOADS.

* FORWARD STRAP LOAD = 54700 + 11140 = 65,840#

* AFT STRAP LOAD = 50500 + 11140 = 61640#

NET STRAP AREA = .937 IN²

$f_t = \dfrac{65{,}840}{.937} = 70{,}200$ PSL

$f_z = 17{,}900$

$f_y = 20{,}100$

$f_x = 15{,}900$

BENDING MODULUS OF RUPTURE APPLIES TO f_y & f_z

FORM FACTOR = 1.5 FOR RECTANGULAR SECT.

$R_t = \dfrac{[illegible]}{[illegible]} = .207$

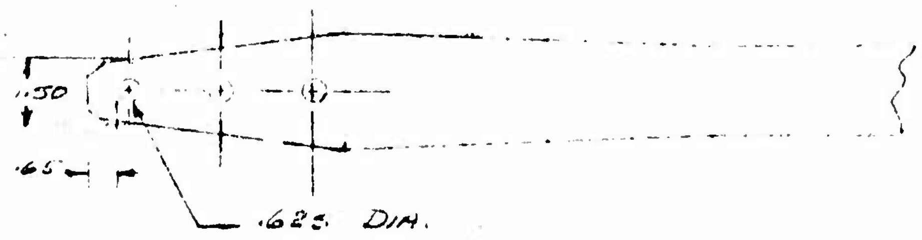
$R_b = \dfrac{[illegible] \times 1.5}{[illegible]} = .760$

$M.S. = [illegible] = \dfrac{1}{.207 + .760} - 1 = +.03$

* ALLOWABLE [illegible] [illegible]ANCE CONDITIONS

ANALYSIS OF STRAP ENDS & BOLT HOLES.

ASSUME THAT THE END BOLT CARRIES 40% OF THE LOAD



AREA IN TENSION

$\frac{1}{2} \times (1.50 - .625) = .437 \ IN^2$

ASSUME THAT 1/3 OF PACK BENDING STRESS IS CARRIED BY EACH BOLT

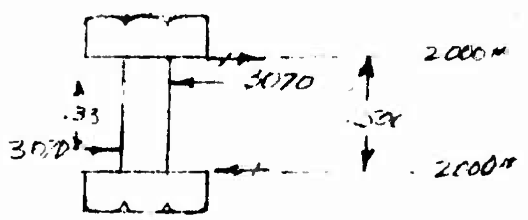
$f_{T\ 2\frac{1}{2}G} = \frac{25280}{.437} + 5600 = 63,452$ PSI (LIMIT)

$M.S. = \frac{164,000}{63,450 \times 1.5} - 1 = \underline{\underline{.69}}$

$f_{T\ WEIGHTED\ FATIGUE} = \frac{20550}{.437} \pm \frac{5??}{.437} \pm 840 = 47,000 \pm 4340$ PSI

BOLT ANALYSIS

FOR THE PURPOSE OF CALCULATING THE FORCE ON THE BOLTS IT WILL BE ASSUMED THAT 1/3 OF THE PACK BENDING STRESS LOAD ACTS ON EACH BOLT. THIS STRESS CAN BE REDUCED TO AN EQUIVALENT COUPLE BY ASSUMING THE FORCES ACTING AT THE CENTROID OF THE STRESS DIAGRAM. THIS GIVES A COUPLE OF 5600 × .33 = 1850 IN LBS FOR 2 1/2 G. OR 560 IN LBS FOR WEIGHTED FATIGUE.



FOR 2 1/2 G MANEUVER

TENSILE FORCE 25,300 + 2000 = 27,300 LBS (LIMIT)

NAS 150 DOUBLE SHEAR ALLOW 58,300

$M.S. = \frac{58,300}{27,300 \times 1.5} - 1 = \underline{\underline{.42}}$

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS HOT CYCLE MODEL 285 REPORT NO. 285-13 PAGE 5.2.3.18

PREPARED BY D.W. NICHOLLS 1-25-6

CHECKED BY

BLADE RETENTION STRAPS

BOLT ANALYSIS (CONT'D)

WEIGHTED FATIGUE

TOTAL TENSILE FORCE *

$20,850 + 1530 \pm 1020 = 20,580 \pm 2550$ LBS

5/8" BOLT AREA = .3068

$f_s = \frac{20,580}{.614} \pm \frac{1530}{.614} + \frac{1020}{.307} = 33,520 \pm 5820$ psi

(DOUBLE SHEAR)

* THE EFFECT OF THE END MEMBER IS SMALL AND IS THEREFORE NEGLECTED.

SHEAR OUT OF BOLTS

SHEAR AREA = $(.65 \times .5)2 = .65$ in^2

2½ G MAN.

$f_s = \frac{25,280 + 3700}{.65} = 44,600$ psi (LIMIT)

$F_s = 94,500$

M.S. $\frac{94,500}{44,600 \times 1.5} - 1 = .41$

WEIGHTED FATIGUE

$f_s = \frac{20580}{.65} \pm \frac{2550}{.65} = 31,660 \pm 3920$ psi

BOLT BEARING IN STRAP

BEARING AREA = $.625 \times .5 = .312$

for 2½ G $= \frac{25,280 + 3700}{.312} = 92,800$ (LIMIT)

$F_{br} = 195,000$

M.S. $\frac{195,000}{92,800} - 1 = 1.10$

8704

5.2.4 Blade Constant Section

The rotor blade configuration and construction from Station 90 to Station 316 is constant. The blade is constructed in segments 12.5 inches in length. Each segment consists of a separate leading edge, center and trailing edge sections. The leading edge and trailing edge overlap and tie structurally to the center section. The center sections are joined spanwise by flexible couplings and tie to the fore and aft spars by 1/4 inch stainless steel bolts, a total of 4 bolts, 2 to each spar. The only spanwise continuous members are the fore and aft spars. Analysis of the spars is in Section 5.2.2 of this report.

The leading edge structure (285-0123) is primarily a fairing and contains steel weights required to balance the blade. The fairing is made from 0.020 corr. res. steel type 301 1/2 H. and is attached to the center section by 8 3/16inch AN 509 screws. The primary loading is centrifugal force. The trailing edge section (285-0117) completes the airfoil section. The trailing edge section is made from 2024-T3 aluminum alloy alclad. The method of construction is that the skins, ribs and webs are bonded together with EPB16-114 using Narmco Metlbond 4021 and the section is attached to the center section with 3/16 inch AN 509 screws. The T. E. section is loaded by centrifugal force and chordwise air pressure.

The center section (285-0113) is the major component of the blade airfoil section. The center section serves several purposes. It acts as a tie to the spars for the leading and trailing edge sections. It is designed to carry torque and chordwise shears but not to carry flapwise bending, therefore, not adding to the bending stiffness of the blade. The inner skin of the blade center section forms the duct that transmits the hot gases at pressure to the tip of the blade. The center section is constructed with two skins, inner and outer, and fore and aft ribs spaced at 1.25 in. O. C. The outer skin and webs are made from corr. res. steel type 301 1/2 H. The ribs and inner skin (duct skin) are made from Rene' 41. The method of attachment is with spotwelds and with seam welds where a pressure seal is required. The elevated temperature distribution in the center section is given in Section 1.

The center sections are connected at the ends by flexible couplings (285-0199). The flexures are designed to absorb the difference in deflections between adjacent center section. The flexures must be as flexible as possible for absorbing the deflections but be structurally satisfactory to transfer torque and chordwise shear between center sections and to resist the duct pressures. The flexures were originally designed to be made of electroformed nickel. Due to procurement problem on the electroform parts, the flexures were fabricated using 0.020 Inconel X sheet, and the stress analysis shown is for the Inconel X Flexures.

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

MODEL 285 REPORT NO. 285-13 PAGE 5.2.4.3

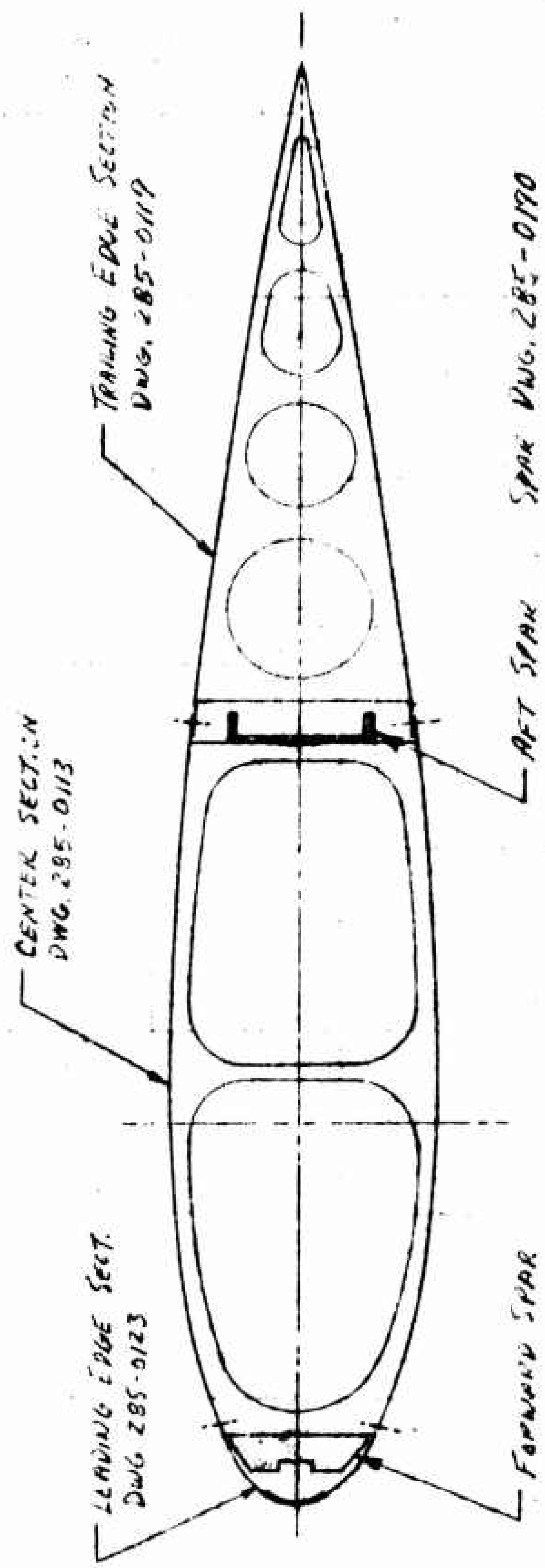
ANALYSIS

PREPARED BY T. Needham 10/31/60

CHECKED BY

BLADE CONSTANT SECTION

BLADE CONSTANT SECTION - STA 90 TO 316



9706

ANALYSIS

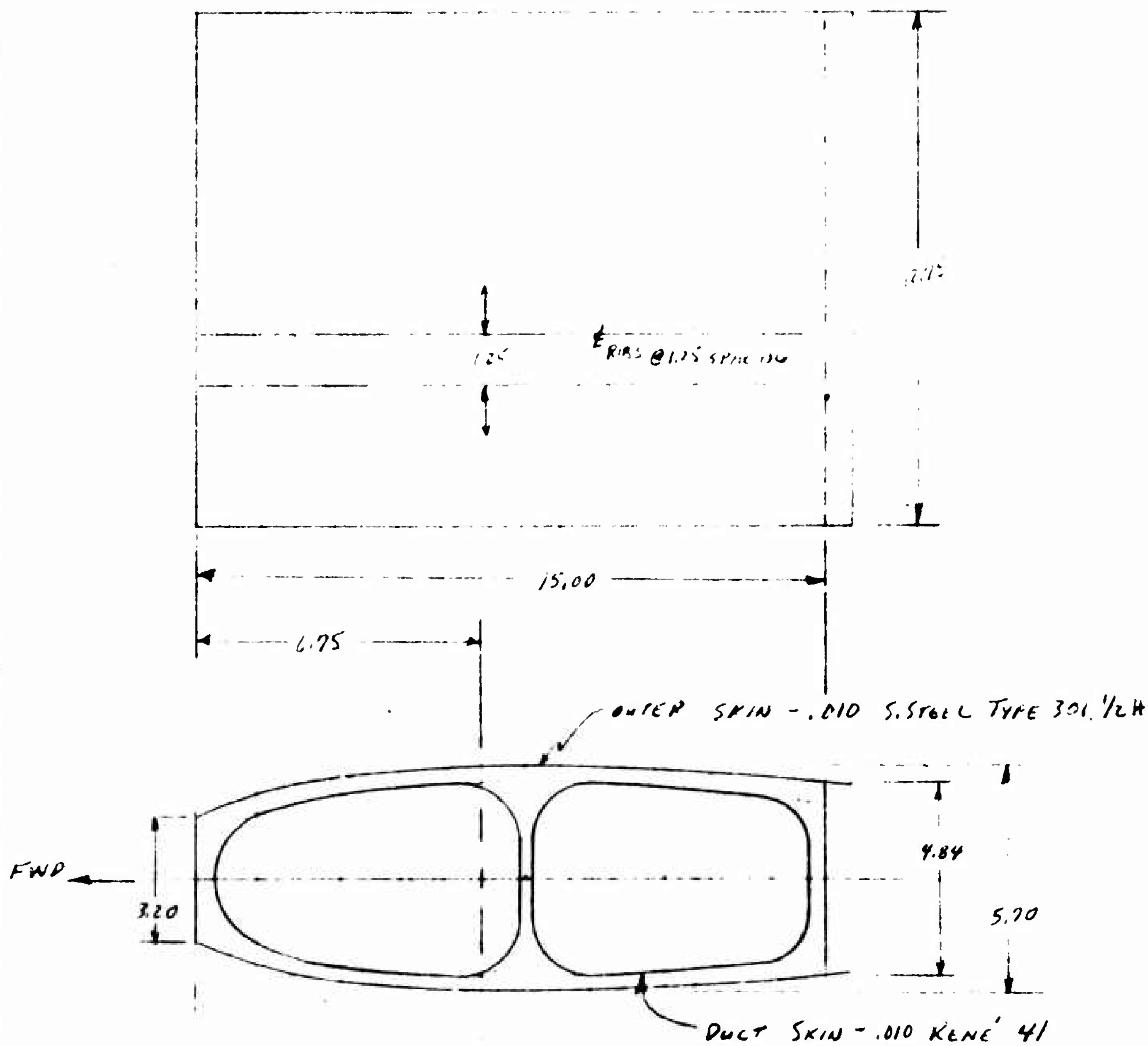
PREPARED BY J. NEEDHAM 2/14/6?

CHECKED BY

BLADE CONSTANT SECTION

GEOMETRY - BLADE SEGMENT

DWG. 285-0113



AREA INCLOSED BY OUTER SKIN = 77.6 IN.^{2}

AREA INCLOSED BY EACH DUCT SKIN = 28. IN.^{2}

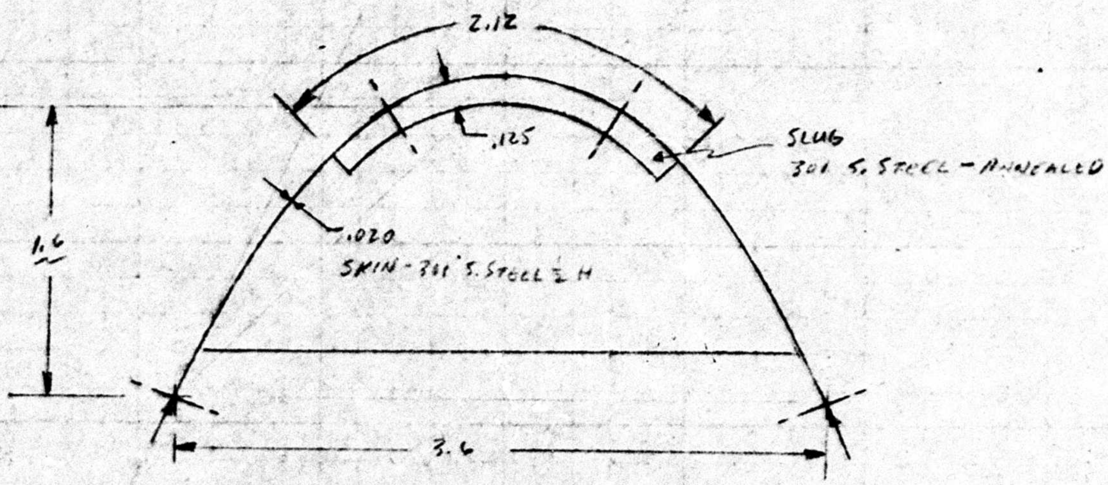
HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS
PREPARED BY J. NEEDHAM 4/14/60
CHECKED BY

MODEL 285 REPORT NO. 285-13 PAGE 5.2.4.5

BLADE CONSTANT SECTION

NOSE FAIRING INSTALLATION - DWG. 285-0123



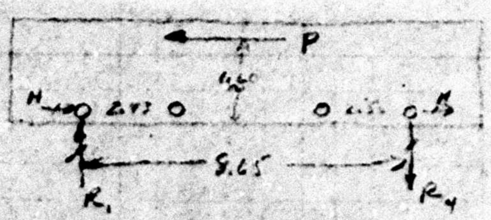
LENGTH OF SLUG = 12.0"

WT. OF SLUG = 12 X .125 X 2.12 X .286 = .865#

OUTB'D SECTION - STA. 316

CENTRIFUGAL 'g' @ STA. 316 FOR OVER-REV COND.

g = 814 LIM.



$P = 814 \times .865 = 704^{\#}$

MAX $R_1 = \frac{704 \times 1.60}{8.65} = 131^{\#}$

9704

NOSE FAIRING INST'L CONT'D

CHECK OF END OF SECTION

ASSUMING A CIRCULAR END SECTION.

REF. ROARK PG 158 CASE 24

$R = \frac{131}{2} = 65.5^{\#}$

$q_s = \frac{65.5}{1.8} = 36.4\ ^{\#}/\text{IN}$

MAX MOM $= .01456\ wR = .01456(65.5)(1.8) = 1.72\ ^{"\#}$

$f_b = \frac{1.72(6)}{(.020)^2} = 25800$ psi LIM.

$F_b \simeq F_{cy} = 118000$ psi (TRANSVERSE) REF. 1 M.S. → HIGH

SECTION @ CENTER OF FAIRING

B. MOM $\cong 131 \times 4.32 = 566\ ^{"\#}$ LIM.

$I = .299(1.8)^3(.020) = .0348\ \text{in.}^4$ $\bar{y}_{max} = .636(1.8) = 1.145$ IN.

$f_b = \frac{566\,(1.145)\,1.5}{.0348} = 28000$ psi ULT.

$F_b \cong F_c = .3 \times 28 \times 10^6 \left(\frac{.020}{1.8}\right) = 93500$ psi

$F_{cy} = 58000$ psi (LONG. DIR.) REF. 1 M.S. $= \frac{58000}{28000} - 1 = 1.07$

ATTACH AT R.

$H = \frac{700}{8} = 88.^{\#}$ $R = 65.5^{\#}$

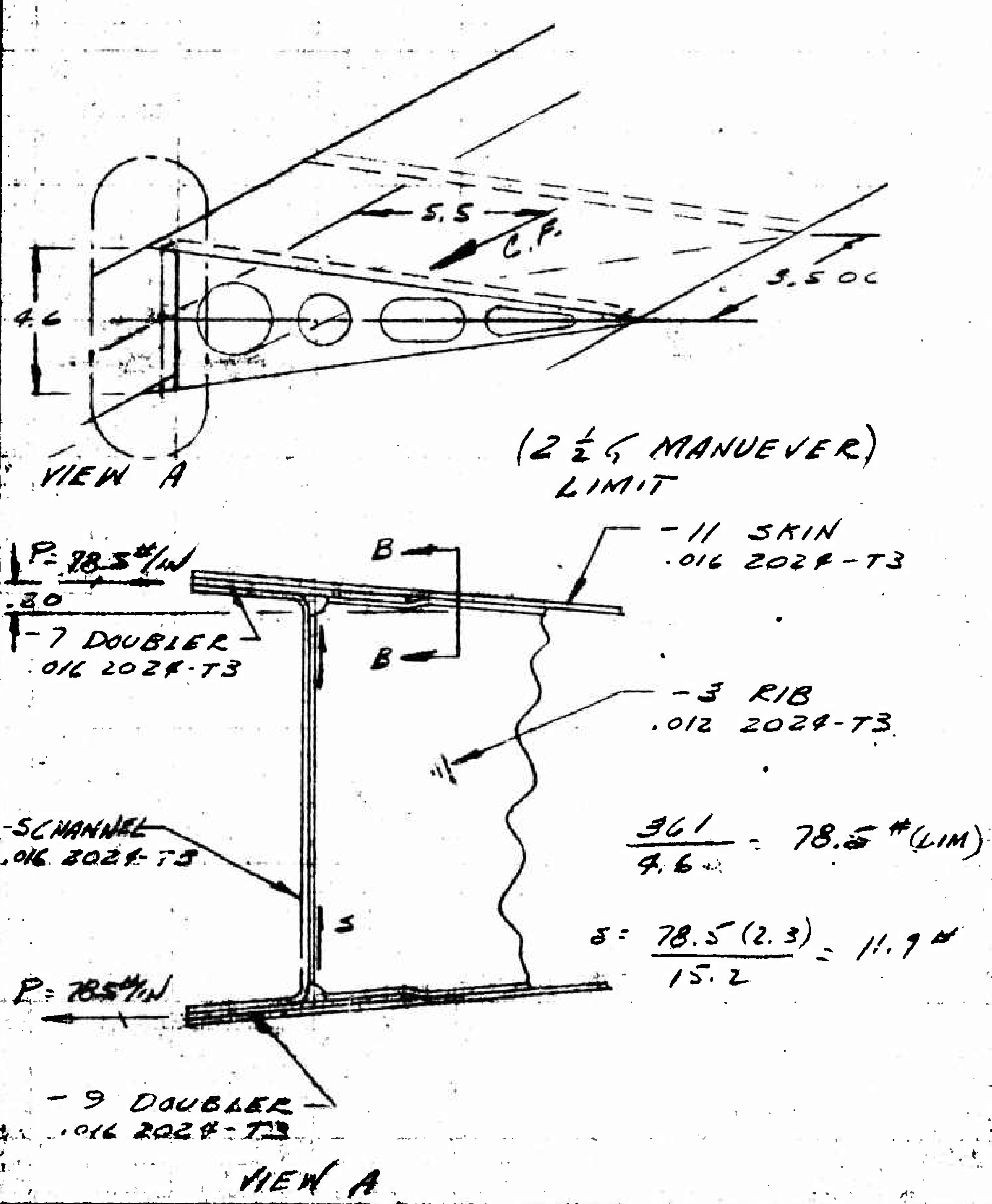
$R_R = \left[(88)^2 + (65.5)^2\right]^{\frac{1}{2}} = 110^{\#}$ LIM.

ALLOW 3/16 (AN509) SCREW DIMPLED IN .020 S STEEL (301 ½H) $\cong$ 550 LBS.

M.S. → HIGH

9706

2-5-0117 SEGMENT ASSEMBLY

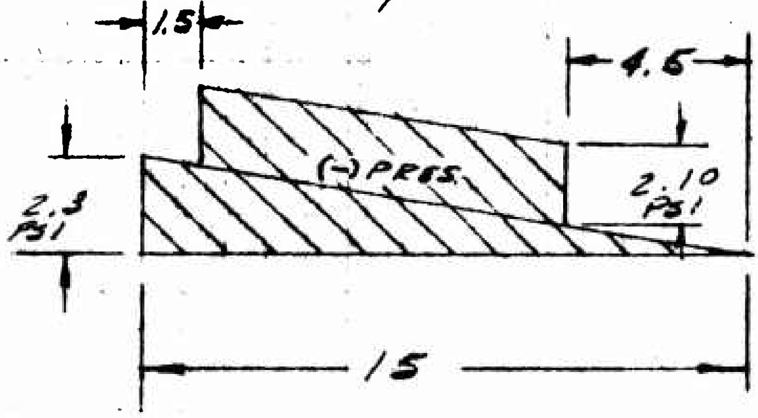


$$\frac{361}{4.6} = 78.5^{\#}(LIM)$$

$$S = \frac{78.5(2.3)}{15.2} = 11.9^{\#}$$

285-0117 SEGMENT ASSEMBLY

($2\frac{1}{2}$G MANUEVER) (LIMIT LOADS)



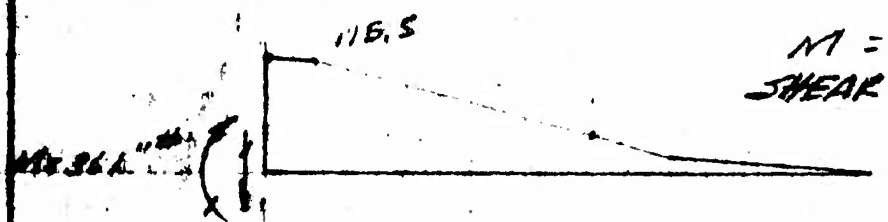
$$M = \frac{1}{2}(2.1)(9)(10.5) + \left(\frac{1}{3}\right)\left(\frac{1}{2}\right)(2.3)(15)^2 \quad \text{REF ROARK}$$

$$94 + 86.5 = 180.5 \; ''\#/\text{IN}$$

OUTB'D - END RIB CRITICAL

$M = 2 \times 180.5 = 361 \; ''\#$

SHEAR = $2 \times 38 = 76\#$



SHEAR = [illegible] -*([illegible])(12) = 52# *REF PREC. PG.

$$P = \frac{M}{4.6} = \frac{361}{4.6} = 78.5\# \quad \text{(LIMIT)}$$

ATTACHMENTS 2.72 O.C.

LOAD/AN 509-10 SCREW

$(78.5 \times 122)\,1.5) = 305\#$

FASTENER ALLOWABLE

AN 509-10SCREW DIMPLED IN .016 & .016
2024-T3 AL. AL. = 493#

$$M.S. = \frac{493}{305} - 1 = .62$$

BLADE - CONSTANT SECTION

285-0117 SEGMENT ASSEMBLY

SKIN CHECK (2½ G MANUEVER) LIMIT

MEMBRANE ANALYSIS

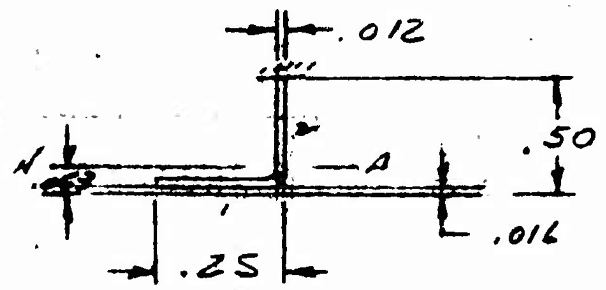
$$\sigma = n \sqrt[3]{p^2 E \frac{a^2}{t^2}} = .23 \sqrt[3]{4^2 \times 10^7 \times \frac{.5^2}{.016^2}}$$

σ = 12,000 psi (Limit)

F_t = 67000 psi REF. 1

$$M.S. \; \frac{67000}{12000(1.5)} - 1 = \underline{HIGH}$$

SECTION B-B



F_{cc}

ITEM	AREA	Y	AY	AY²	I_o
1	.007	.014	.00007	—	.00005
2	.006	.270	.00162	.00044	
Σ	.013		.00169	.00044	

F_{cc} = 25,000 psi

effective b/t = 9

$$\bar{y} = \frac{.00169}{.270} = .063 \text{ IN}$$

I = .00044 + .00005 − .00169(.063) = .00038 IN^4

$$f_c = \frac{P}{A} = \frac{78.5(1.5)}{.013} = 9080 \text{ psi (ULT)}$$

285-0117 SEGMENT ASSEMBLY AFT

SEGMENT C.F. $2\frac{1}{2}$ G MANUEVER

$C.F. = MR\omega^2$ or $W g$

$CF = .931(535) = 498\#$ (LIMIT)

MOMENT IS REACTED BY THE END RIBS AS A COUPLE. THE END RIBS ARE 11.0 IN O.C.

$M = 498(5.4) = 2690''\#$

$2P' = \frac{2750}{11} = 244\#$

$P' = 122\#$ (Limit)

$f_{p'} = \frac{122}{.013}(1.5) = 14,100$ psi

$f_b = 14100 + 9080 = 23180$ psi (comp)

$M.S. = \frac{25000}{23180} - 1 = .08$

SHEAR (SKIN BUCKLING)

$f_s = \frac{498}{2 \times 12} = 21\ \#/IN$

F_s FOR .016 2024-T3 AL AL SHT = WITH STIFFENERS 3.5 O.C. =

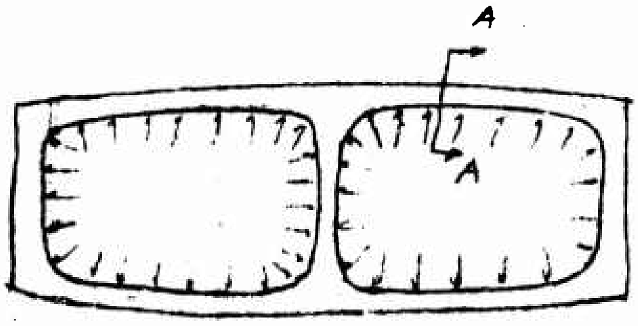
$b/t = \frac{3.5}{15} = .233 \quad K_s = 8.9$

$F_s = 8.9 \times 10.8 \times 10^6 \left(\frac{.016}{3.5}\right)^2 = 1960$ psi

$1960(.016) = 31.4\#/IN \qquad M.S. = \frac{31.4}{21} - 1 = .50$

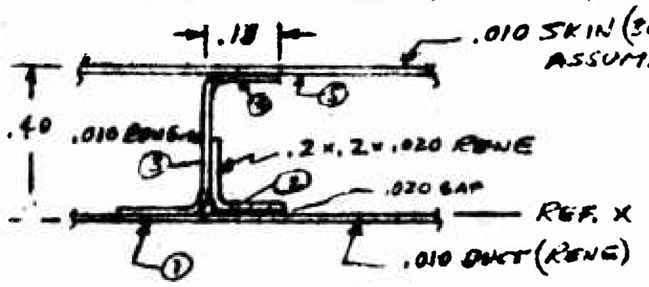
RIB ANALYSIS

THE RIBS ARE SUBJECTED TO THERMAL STRESSES IN ADDITION TO SUPPORTING PRESSURE LOADING FROM DUCT PRESSURE AND EXTERNAL AIRLOAD PRESSURE.



p (DUCT) = 30 PSIG (LIM.)

SECTION A-A (TYPICAL)



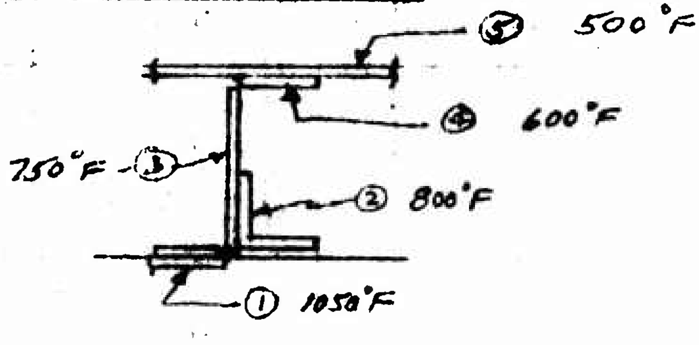
ITEM	A	Y	$AY \times 10^4$	$AY^2 \times 10^4$	$I_o \times 10^4$
1	.0036	0	—	—	—
2	.0080	.07	5.6	.392	—
3	.0036	.19	6.85	1.300	.458
4	.0018	.375	6.75	2.530	—
5	.0060	.385	23.05	8.900	—
	.0230		42.25	13.322	.458

$$\bar{Y} = \frac{.004225}{.0230} = .184$$

$$I_{NA} = .0000458 + .0013322 - .184(.004225) = .000603 \text{ IN.}^4$$

RIB ANALYSIS (CONT'D)

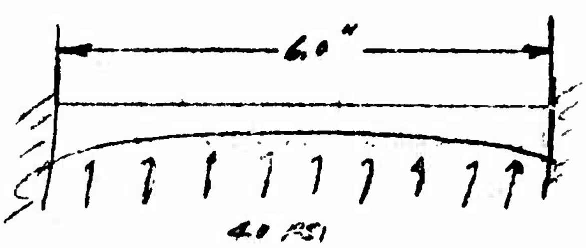
THERMAL STRESS



ITEM	A	$\Delta T°$	$\alpha \times 10^{-6}$	$E \times 10^6$	f'	ΔP	$f'' = \frac{\Sigma \Delta P}{\Sigma A}$	f_{RES}
1	.0036	980	7.8	27	-206,000	-742	148,000	-58,000
2	.0080	730	7.8	28	-160,000	-1280	↓	-12,000
3	.0036	680	7.8	28	-149,000	-536		-1,000
4	.0018	580	7.8	29	-120,000	-216		28,000
5	.0060	430	9.4	26	-105,000	-630	148,000	43,000
	.0230					-3404		

PRESSURE & AIRLOADS

USE 40 PSI INTERNAL & NEGLECT AIRLOAD. —



ASSUME FIXITY AT ENDS OF EACH BAY.

$w = 40(1.25) = 50\ \#/\text{IN. (LIM.)}$

$M_{CENTER} = \frac{w l^2}{24}$

$= \frac{50(6)^2}{24} = 75\ ''\#\ \text{LIM.}$

$= 112.5\ ''\#\ \text{ULT.}$

CHECK ITEM ① $I = .000603\ \text{IN.}^4$, $Y = .184\ \text{IN.}$

$f_b\,(\text{AIRLOAD}) = -\frac{112.5(.184)}{.000603} = -34,400\ \text{PSI}$

$f\,(\text{TOT}) = -58,000 - 34,400 = -92,400\ \text{PSI.}$

$b/t = .18/.010 = 18$. $F_{cc} = 69,000\ \text{PSI.}$ REF. SECT. 2.

Flange will buckle and airload stress transferred to

RIB ANALYSIS (CONT'D.)

item ② angle.

$\Delta P = (92,400 - 69,000).0036 = 84$ LBS.

CHECK ITEM ③ $Y = .154$ (FLANGE)

f_b (AIRLOAD) $= \frac{-112.5(.154)}{.000603} = -28,800$ PSI

Δf_b (FROM ITEM ②) $= \frac{84(.184)}{.154(.0040)} = -25000$ PSI

$f_{TOT.} = -28,800 - 25000 - 12000 = -65800$ PSI

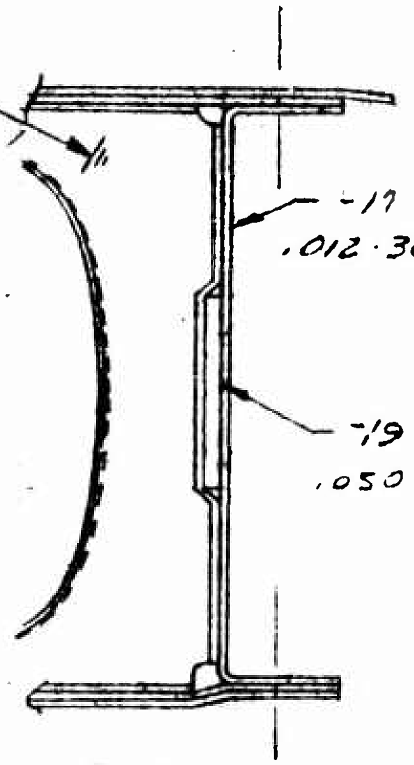
$b/t = 10$ $F_{cc} = 108,000$ PSI. REF. RPT 285-13 SECT. 2.

TEMP. RED. FACTOR ≅ .90

$M.S. = \frac{108,000(.90)}{65800} - 1 = \underline{\underline{.48}}$

The above analysis neglects the tension stress from the pressure end loads. - (CONSERVATIVE)

285-0113 SEGMENT ASSY



C F LOAD OF SECTION @ 875 '/sec

WEIGHT OF SECTION .65 #/IN (RUNNING)
LENGTH " " 12.5 IN

$C.F. = m r \omega^2$ $\omega = 31.53$ rad/sec

$m = \frac{W}{g(12)} = \frac{(.65)(12.5)}{(32.2)(12)}$

$C.F. = (31.53)^2 325 (.021)$

$C.F._{OVER\ REV} = 6760^{\#}$ (Limit) $r = 325$ IN

$C.F._{CRUISE} = 4400^{\#}$ (Limit)

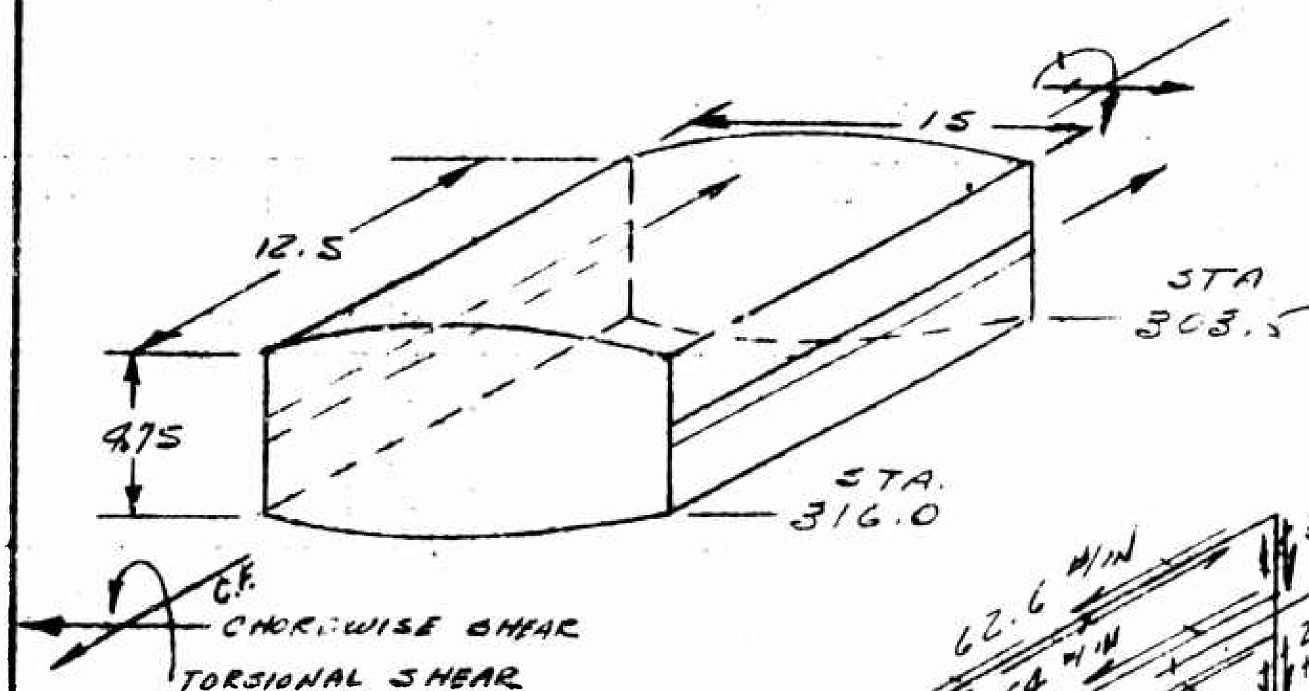
SECTION IS ATTACHED TO THE SPAR IN 4 PLACES WITH NAS 144 BOLTS BEARING IN .050 DOUBLER & .012 WEB MADE OF TYPE 301 ½ H CRES.

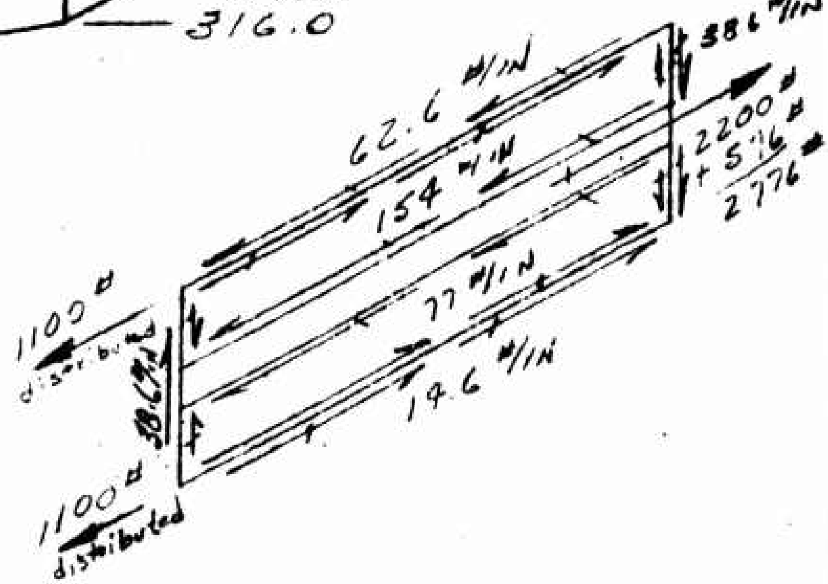
285-0113 SEGMENT ASSY

C.F. = 4400 # LIM

$f_{s(T)}$ = 3500 ± 2500 = 6000/155.2 = 38.6 #/IN

$f_{s(c)}$ = 200 ± 520 = 720/30 = 24 #/IN





CRITICAL PANEL
CRITICAL LOADING
LIMIT LOADS FOR
BUCKLING SHEAR

@ BLADE STA 200

C.F. = 2590 # $\frac{2590}{(4)(12)}$ = 54 #/IN

$f_{s(T)}$ = 11,000 ± 8250 = 19250/155.2 = 124 #/IN

$f_{s(c)}$ = 200 ± 520 = 720/30 = 24 #/IN

285-0113 SEGMENT ASS'Y

ATTACHMENT OF SEGMENT TO SPAR. MAXIMUM LIMIT LOAD ON ONE 1/4 IN. DIA. BOLT IS 2776 LBS. REF. PRECEEDING PAGE.

THE BOLT BEARS IN A .012 WEB AND .050 DOUBLER STRAP.

LIM. BEARING STRESS $f_{br_y} = \dfrac{2776}{.25 \times .062} = 179\,000$ psi

ALLOWABLE $F_{br_y} = 200\,000 \times \overset{*}{.90} = 180\,000$ psi REF.(1)

* TEMP. REDUCTION FACTOR

$$M.S. = \frac{180\,000}{179\,000} - 1 = \underline{\underline{.01}}$$

-17 WEB (TYPE 301 1/2 H CRES. RES. STEEL .012 THICK)

$$q_{s_{MAX}} = \frac{12600 \pm 9500}{155.2} \pm \frac{520}{30} = 81.2 \pm 88.5 = 169.7 \text{ \#/IN.}$$

STIFFENERS ARE SPACED AT 1.25 IN. O.C.

$$F_{s_{cr}} = \frac{K_s \pi E}{12(1-\mu^2)}\left(\frac{t}{b}\right)^2 = 8 \times 28.5 \times 10^6 \left(\frac{.012}{1.25}\right)^2 = 21000 \text{ psi}$$

$$Q_s = 21000 \times .012 = 252 \text{ \#/IN.}$$

$$M.S. = \frac{252\,(\overset{*}{.84})}{169.7} - 1 = \underline{\underline{.25}}$$

@ BLADE STA. 200 FROM PRECEEDING PAGE

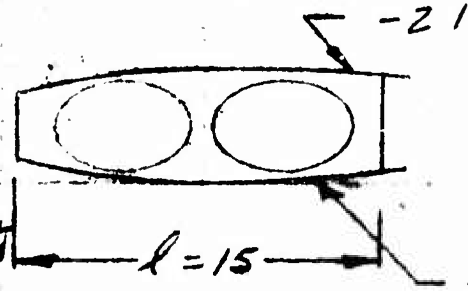
$$q_{s_{MAX}} = 24 + 3.. / 124 = 202 \text{ \#/IN}$$

$$M.S. = \frac{252\,(\overset{*}{.84})}{202} - 1 = \underline{\underline{.05}}$$

NOTE: THE CYCLIC TORSION AND CHORDWISE SHEAR WERE LOWERED MAKING THE ABOVE MARGINS OF SAFETY CONSERVATIVE. THE MAX. CYCLIC SHEAR FLOW IS ±60 #/IN INSTEAD OF ±88.5 #/IN.

285-0113 SEGMENT ASSY

CONSTANT SECTION



AREA = 155.2 in $\ell = 15$

FRAMES 1.25 O.C.

$$F_{BUCKLING} = \frac{K_s \pi^2 E}{12(1-\mu^2)}\left(\frac{t}{b}\right)^2 + K_2 E\left(\frac{t}{R}\right) \quad \text{REF. ③}$$

FROM CURVES $\dfrac{K_s \pi^2}{12(1-\mu^2)} = 8$

$$F_{BUCK} = (8)\, 28.5\times10^6\left(\frac{.010}{1.25}\right)^2 + .10\,(28.5\times10^6)\frac{.010}{20}$$

$$F_{BUCK} = 14600 + 14250 = 28{,}850 \text{ psi}$$

$$= 288.5\ \#/\text{IN}$$

TORSION (WEIGHTED FATIGUE)

12600 ± 9500 "#

SHEAR (WEIGHTED FATIGUE)

± 520 #

$$f_s = \frac{12600 \pm 9500}{155.2} \pm \frac{520}{30}$$

$$f_s = 81.2 \pm 88.5\ \#/\text{IN} = 169.7\ \#/\text{IN}$$

$$M.S. = \frac{288.5}{169.7} - 1 = \underline{.69}$$

WILL NOT BUCKLE

BASIC FLEXING

CYCLIC DEFLECTIONS & ROTATIONS - W. F. COND.

STRESSES: (REF. SPAR ANALYSIS SECT. 5.2.2)

FRONT SPAR		REAR SPAR	
STA. 90, $h/t = 1.50$	$f_c = \pm 1940$ psi; $f_b = \pm 4870$	STA. 90, $h/t = 1.59$	$f_c = \pm 3830$ psi; $f_b = \pm 5160$
STA. 240, $h/t = 1.50$	$f_c = \pm 460$; $f_b = \pm 11920$	STA. 240, $h/t = 1.45$	$f_c = \pm 1340$; $f_b = \pm 11330$

SPAR AXIAL DEFLECTIONS

FRONT SPAR

STA. 90 $\quad \dot{\delta}_x = \frac{\pm 1940}{15 \times 10^6}(12.5) = \pm .00162$ ''

STA 240 $\quad \dot{\delta}_x = \frac{\pm 460}{15 \times 10^6}(12.5) = \pm .00038$

REAR SPAR

STA. 90 $\quad \bar{\delta}_x = \frac{\pm 3830}{15 \times 10^6}(12.5) = \pm .00319$ ''

STA 240 $\quad \bar{\delta}_x = \frac{\pm 1340}{15 \times 10^6}(12.5) = \pm .00112$

SPAR BENDING ROTATIONS

FRONT SPAR

STA. 90 $\quad \dot{\theta} = \frac{\pm 4870\,(12.5)}{1.50 \times 15 \times 10^6} = \pm .00270$ RAD.

STA. 240 $\quad \dot{\theta} = \frac{\pm 11920\,(12.5)}{1.50 \times 15 \times 10^6} = \pm .00651$ RAD.

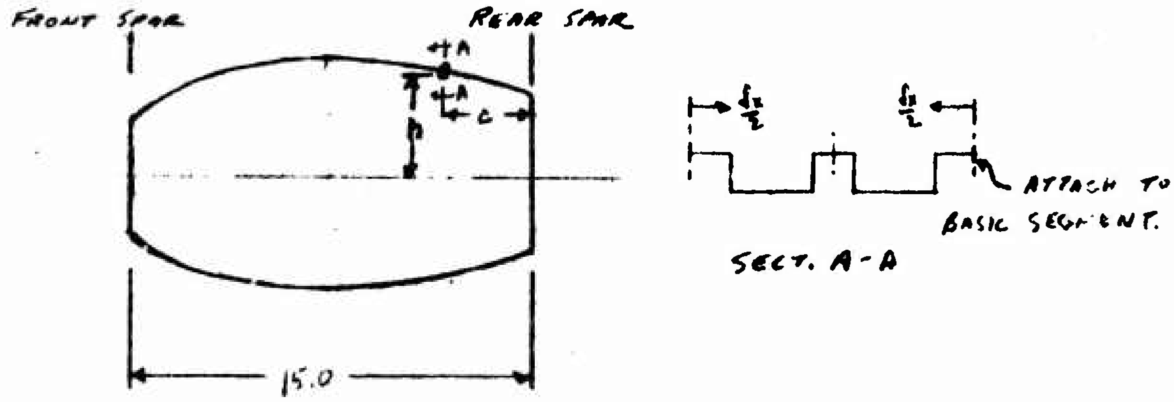
REAR SPAR

STA. 90 $\quad \bar{\theta} = \frac{\pm 5160\,(12.5)}{1.59 \times 15 \times 10^6} = \pm .00271$ RAD.

STA. 240 $\quad \bar{\theta} = \frac{\pm 11330\,(12.5)}{1.45 \times 15 \times 10^6} = \pm .00652$ RAD.

BASIC FLEXURE

DEFLECTION @ ANY POINT ON FLEXURE



STA. 90

$$\delta_x = \pm.00270\,h \overset{\Delta}{\pm} (\pm.00319 \mp .00032\,c)$$

STA. 240 $\quad\quad$ Δ CAN BE $\pm$ OR $\mp$

$$\delta_x = \pm.00652\,h \overset{\Delta}{\pm} (\pm.00112 \mp .00010\,c)$$

DEFLECTIONS DUE SPAR STEADY STRESSES

REAR SPAR

STA. 90

$$\delta_x = \frac{42000 \times 12.5}{15 \times 10^6} = .0350''$$

STA. 240

$$\delta_x = \frac{39700 \times 12.5}{15 \times 10^6} = .0330''$$

FRONT SPAR

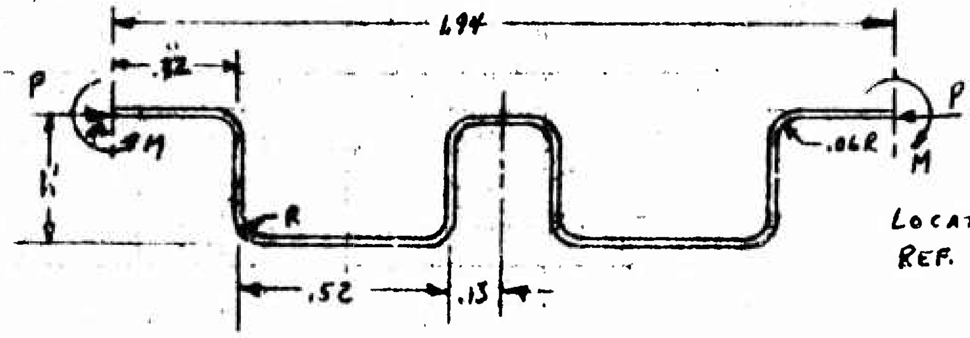
STA. 90

$$\delta_x = \frac{25700 \times 12.5}{15 \times 10^6} \quad .0214''$$

STA. 240

$$\delta_x = \frac{16500 \times 12.5}{15 \times 10^6} = .0138''$$

BASIC FLEXURE - .020 INCONEL 'X'
DWG. 285-0199



LOCATION @ λ = 2.96 ξ = 4.3
REF. SKETCH PREVIOUS PAGE

WHERE $h' = .35$ IN (MINIMUM AND THE CRITICAL SECTION)

$R = .07$ $\quad h = .35 - 2 \times .07 = .21$

$d_1 = .25$ $\quad d_2 = .52 - .14 = .38$ $\quad d_3 = .13 - .07 = .06$

FOR ROTATION @ 'a' = 0 (MAX. MOMENT)

$$M = P\left\{\frac{h^2 + 7.142hR + 6.252R^2 + h d_2 + 2.00 R d_2}{d_1 + d_2 + d_3 + 6.284R + 2.00h}\right\}$$ (FROM A STRAIN-ENERGY ANALYSIS)

$$= P\left\{\frac{(.21)^2 + 7.142(.21)(.07) + 6.252(.07)^2 + (.21)(.38) + 2.0(.07)(.38)}{.25 + .38 + .06 + 6.284(.07) + 2.0(.21)}\right\}$$

$$= \left(\frac{.3105}{1.540}\right) P = .202\,P$$

IN PREVIOUS ANALYSES M WAS ASSUMED TO EQUAL

$(\tfrac{1}{2} h')P$ OR $.5 \times .35P = .175\,P$

ANALYSIS
PREPARED BY J. NEEDHAM 4/20/61
CHECKED BY

CONSTANT BLADE SECTION

BASIC FLEXURE — .020 INCONEL 'X'.

MIN. DEPTH SECTION ($h' = .35$)

FOR MAX. FIXITY AT EDGE ATTACHMENT (MAX M).

$M = .202\,P$

$$EI\,\delta_x = P[.667h^3 + 7.142Rh^2 + 14.28R^2h + 9.22R^3 + d_2(h+2R)^2]$$
$$-M[1.0\,h^2 + 7.142Rh + 6.284R^2 + d_2(h+2R)]$$
$$= P[.667(.21)^3 + 7.142(.07)(.21)^2 + 14.28(.07)^2(.21) + 9.22(.07)^3 + .38(.21+.14)^2]$$
$$-.202P[1.0(.21)^2 + 7.142(.07)(.21) + 6.284(.07)^2 + .38(.21+.14)]$$
$$= (.0926 - .0632)P = .0294\,P \quad \text{(FOR 1/2 OF FLEXURE)}$$

$$\delta_x = \pm.00652(2.96) \pm[\pm.00112 \mp .00010(4.3)] = \pm.0188 \text{ IN.}$$

E @ R.T $= 31\times10^6$ @ 600°F $= .89\times31\times10^6 = 27.6\times10^6$

INCLUDING WIDE PLATE EFFECT

$$E \text{ @ } 600° = \frac{27.6\times10^6}{1-(.3)^2} = 30.3\times10^6$$

$$I = 1.0(.02)^3/12 = .666\times10^{-6}$$

$$EI\,\delta_x = 30.3\times10^6 \times .666\times10^{-6}(\pm.0188) = \pm.38$$

$$P = \frac{\pm.38}{2\times.0294} = \pm6.46^{\#}$$

MAX $M = .202(\pm6.46) = \pm1.31$ "#

$$f_b = \frac{6(\pm1.31)}{(.020)^2} = \underline{\pm19600}\text{ psi} \quad \begin{cases}\text{AT ATTACHMENT TO SKIN} \\ \text{\& AT FLEXURE } ℄.\end{cases}$$

AT LOWER HAT $M = (.35-.202)(\pm6.46) = \pm.956$ "#

$$f_b = \frac{6(\pm.956)}{(.02)^2} = \pm14350\text{ psi}$$

8704

CONSTANT BLADE SECTION

BASIC FLEXURE — .020 INCONEL 'X'

MIN. DEPTH SECTION — FREE TO ROTATE AT EDGE ATTACHMENT

$M = 0$

$\therefore EI\delta_x = .0695 P$ (½ of FLEXURE)

$EI\delta_x = \pm .380$

$P = \dfrac{\pm .380}{2 \times .0926} = \pm 2.05^{\#}$

MAX MOMENT AT INNER LOOP $= .35(\pm 2.05) = \pm .718$ "#

$f_b = \dfrac{6(\pm .718)}{(.020)^2} = \pm 10800$ psi

INFLECTION POINT ASSUMED AT MID-POINT OF SIDES

$M = .5(.35)P = .175P$

$EI\delta_y = (.0926 - \overset{.0548}{.175 \times .313})P = .0378 P$

$P = \dfrac{\pm .38}{2 \times .0378} = \pm 4.90^{\#}$

$Mom = \pm 4.90(.175) = \pm .857$ "#

$f_b = \dfrac{6(\pm .857)}{(.020)^2} = \pm 12900$ psi

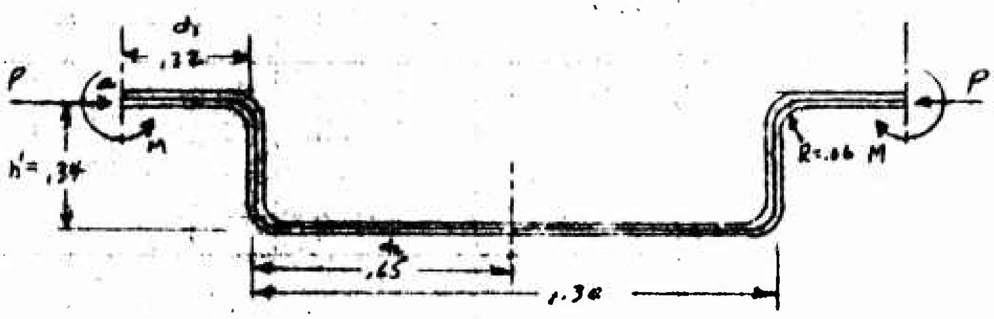
THE MAXIMUM CYCLIC BENDING STRESS IS AT THE ATTACHMENT TO THE SKIN OR AT THE FLEXURE CENTERLINE.

$f_b = \pm 19600$ psi

CONSTANT BLADE SECTION

BASIC FLEXURE – .020 INCONEL 'X'

SECTION AT SPAR ℄



ROTATION OF POINT (a)

$$EI\theta = P\left[.5h^2 + 3.571hR + 3.141R^2 + hd_2 + 2.00Rd_2\right]$$
$$- M\left[d_1 + d_2 + 3.142R + 1.0h\right]$$

FROM A STRAIN-ENERGY ANALYSIS

WHERE $h = .34 - 2 \times .07 = .20$ $R = .07$

$d_1 = .32 - .07 = .25$ $d_2 = .65 - .07 = .58$

FOR ROTATION AT 'a' = 0 (MAX M)

$$M = P\left\{\frac{.5(.20)^2 + 3.571(.20)(.07) + 3.141(.07)^2 + .20(.58) + 2.0(.07)(.58)}{.25 + .58 + 3.142(.07) + 1.0(.20)}\right\}$$

$$= P\left(\frac{.2837}{1.25}\right) = .226P \qquad M_{@℄} = (.340 - .226)P = .114P$$

WHERE INFLECTION POINT IS ASSUMED AT CENTER OF SIDES

$$M = .5(.34)P = .170P$$

BASIC FLEXURE - .020 INCONEL 'X' - @ SPAN ℄

CYCLIC DEFLECTION OF FLEXURE $= \pm .0054''$

$$EI\,\delta_x = 30.3\times10^6 \times .666\times10^{-6}(\pm .0054) = \pm .109$$

$$EI\,\delta_x = P\left[.667h^3 + 7.142\,Rh^2 + 14.28\,R^2h + 9.22\,R^3 + 2d_2(h+2R)^2\right]$$
$$-M\left[1.0h^2 + 7.142\,Rh + 6.284\,R^2 + 2\,d_2(h+2R)\right]$$
$$= P\left[.667(.20)^3 + 7.142(.07)(.20)^2 + 14.28(.07)^2(.20) + 9.22(.07)^3 + 2(.58)(.34)^2\right]$$
$$-M\left[1.0(.20)^2 + 7.142(.07)(.20) + 6.284(.07)^2 + 2(.58)(.34)\right]$$
$$= .1765P - .565M$$

5.34
20.0
14.0
3.16
134
.176.5

FOR FULL FIXITY AT EDGE ATTACHMENT (M_{max}) AND BASE OF FLEXURE 100% EFFECTIVE. ($t = .020$)

$$EI\,\delta_x = .1765P - .565(.226P) = .0487P = \pm .109$$

$$P = \frac{\pm .109}{.0487} = \pm 2.28^{\#} \qquad M = \pm .515''^{\#}$$

$$f_b = \frac{\pm .515\times6}{(.020)^2} = \pm 7820\ psi$$

.040
.100
.471
.454
.565

FOR BASE 25% EFFECTIVE -

$$M_{MAX} = P\left[\frac{.0854 + .25(.1993)}{.67 + .25(.58)}\right] = \frac{.1348}{.815}P = .165P$$

$$EI\,\delta_x = \left[.0425 + .25(.134)\right]P - .165P\left[.171 + .25(.354)\right] = .0316P$$

$$P = \frac{\pm .109}{.0316} = \pm 3.44^{\#} \qquad M = .175(\pm 3.44) = \pm .603''^{\#}$$

$$f_b = \frac{\pm .603\times6}{(.020)^2} = \pm 9050\ psi$$

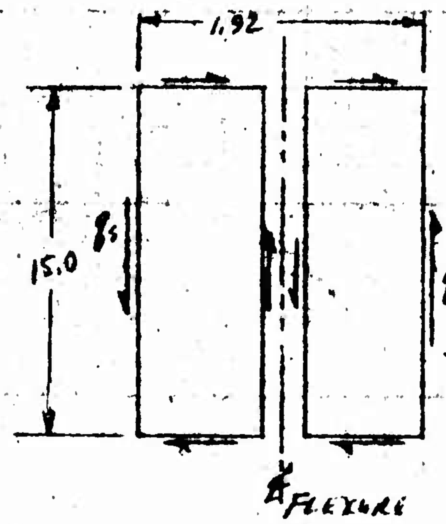
WITH THE FLEXURE SPOTWELDED TO THE REINFORCING ... AND USING COMBINED THICKNESS ($t = .020 + .025 = .045$)

$$f_b = \pm 9050\left(\frac{.045}{.020}\right) = \pm 20400\ psi$$

CONSTANT BLADE SECTION

BASIC FLEXURE - .020 INCONEL 'X'

CHORDWISE SHEAR LOADING

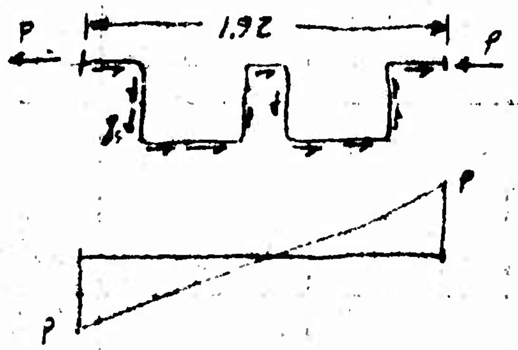


FOR WEIGHTED FATIGUE CONDITION

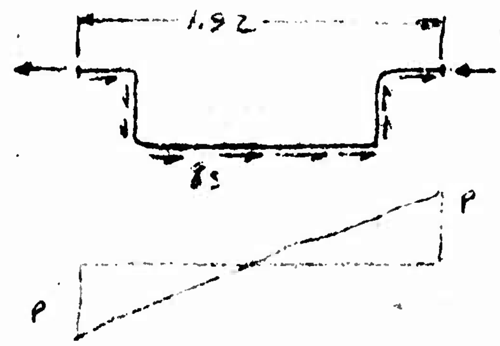
$q_s = \pm 12.8$ #/IN

END SHEAR FLOW ON FLEX. SECTIONS

MIN. DEPTH SECTION



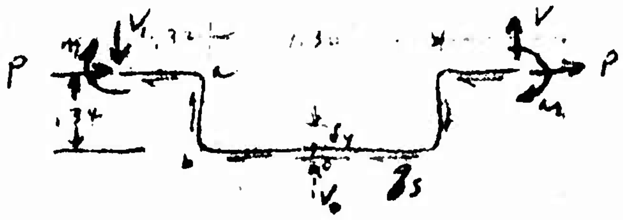
SECTION @ SPAR ℄



$P = .5 \times 1.92\, q_s = .96\, q_s$

BASIC FLEXURE — .020 INCONEL 'X'

@ ℄ SPAR — FOR CHORDWISE SHEAR



$$EI\delta_Y = V_0\left[d_2^2h + \frac{(d_2+d_1)^3}{3}\right] - g_s\left[\frac{d_2^2h^2}{2} - \frac{hd_1^3}{3} + h\,d_2^2\,d_1\right]$$

$h = .34 \quad d_1 = .32 \quad d_2 = .65$

$\delta_Y = 0$ FOR UNIFORM SHEAR FLOW (g_s)

$$V_0 = g\left\{\frac{\frac{(.65)^2(.34)^2}{2} - \frac{(.34)(.32)^3}{3} + (.34)(.65)^2(.32)}{(.65)^2(.34) + \frac{(.97)^3}{3}}\right\}$$

.0244 .00037 .0460 .1435 .304

$V_1 = V_0 + h g_s$

$V_0 = g\left[\frac{.0667}{.448}\right] = .149\,g_s \qquad V_1 = .149 + .34 g_s = .489\,g_s$

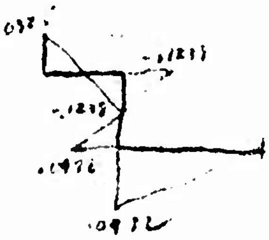
$M_0 = h g_s d_1 + V_0 d - d_2 h g_s \quad - V_0 d + (d_1 - d_2) h g_s$

$= (.34)(.32)g_s + .149 g_s(.97) - (.65)(.34) g_s = .0325\,g_s$

$M_a = .0325\,g_s - .489(.32)g_s = -.1238\,g_s$

$M_b = -.1238 g_s + (.97 - .32).34\,g_s = .0972\,g_s$

$M_0 = .0972 g_s - (.489 - .34).65\,g_s = .0003 g_s \cong 0$ ✓



DISTRIBUTING CHORDWISE SHEAR COUPLE LOAD OVER 3" OF FLEXURE GIVES

$g_s = \frac{1.92(\pm 12.8)}{3} = \pm 8.2$ #/IN.

MAX MOM = $\pm 8.2 \times .1238 = \pm 1.02$ "#

$f_b = \frac{\pm 1.02(6)}{(.020)^2} = \pm 15300$ psi

USING COMBINED t OF FLEX. & REINF. HAT (.020 + .025) = .045

$f_b = \frac{\pm 1.02(6)\,1.5}{.2025} = \pm 4500$ psi

CONSTANT BLADE SECTION

BASIC FLEXURE

SECTION AT SPAR & COMBINED STRESSES FOR CYCLIC DEFLECTION STRESSES AND FOR CHORDWISE SHEAR STRESSES.

IN ANALISING THE FLEXURE AS A SINGLE LAYER OF .020 INCONEL 'X'

DEFLECTION $f_b = \pm 9050$ PSI

CHORDWISE SHEAR $f_b = \pm 15200$ PSI

COMBINED CYCLIC $f_b = \pm 24250$ PSI

IN ANALISING THE FLEXURE USING THE COMBINED THICKNESS OF THE FLEXURE AND REINFORCING HAT i.e. $t = .020 + .025 = .045$ IN.

DEFLECTION $f_b = \pm 20400$ PSI

CHORDWISE SHEAR $f_b = \pm 4500$ PSI

COMBINED CYCLIC $f_b = \underline{\underline{\pm 24900}}$ PSI

5.2.5 Blade Tip

5.2.5.1 Description

The blade tip section consists of the portion of the rotor blade outboard of Station 316 including the tip cascade. The tip section from Station 316 to the tip cascade serves the same function and is of the same construction as the blade constant section described in Section 5.2.4 of the report. The purpose of the tip cascade is to turn the flow of the duct gases producing the force that turns the rotor blade. The tip cascade is constructed from Haynes 25 cobalt base material.

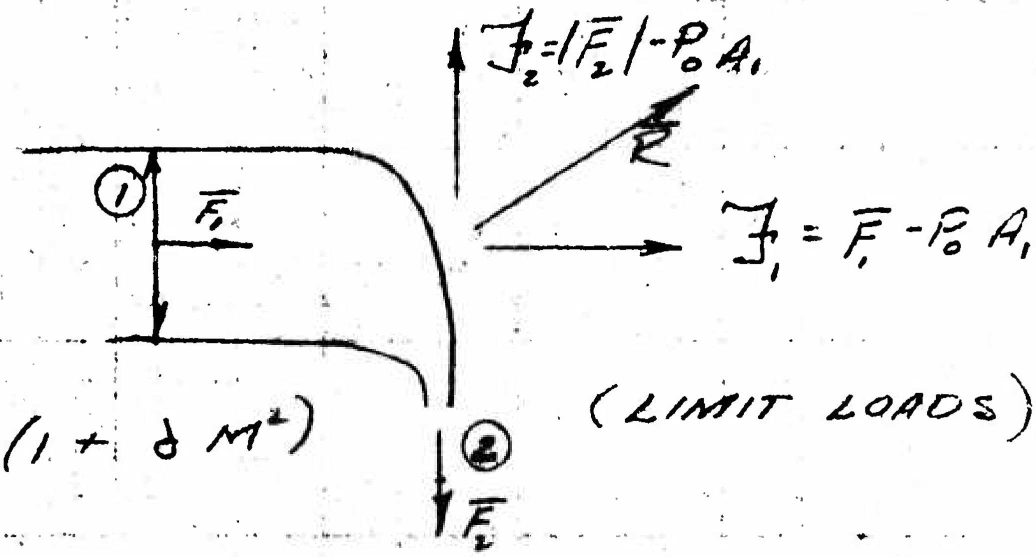
The stresses in the cascade are produced by gas pressure, centrifugal force, and thermal effects. The tip cascade ties to the tip constant section with 3/16 inch steel screws. The constant tip section in addition to carrying its own loads also transfers the centrifugal force and pressure loads from the tip cascade to the spars and supporting structure.

Weight is extremely important at the blade tip since centrifugal force in g's at Station 333 for the normal condition is 548 limit and for the over-rev. condition is 857 limit.

64
21/1
9

285-0192 BLADE TIP

LOADS ON THE TURNING VANES - TOTAL



$F = PA(1 + \gamma M^2)$

(LIMIT LOADS)

DESIGN CONDITIONS

$P_{t_1} = 26.4$ psig $= 41.1$ psia

Sea Level $\qquad P_0 = 14.7$ psia

$T_{t_1} = 1200°R$

$A_2 \cong 35\ IN^2 \qquad A_1 = 56.0\ IN^2$

$M_2 = 1 \qquad M_1 = .40$

$\frac{P_1}{P_{t_1}} = .90 \qquad \frac{P_2}{P_{t_2}} = .53$

$P_1 = 37$ psia $\qquad P_2 = 21.8$ psig

$F_1 = 37 \times 56 (1 + 1.4 \times .16) = 2{,}550\ \#$

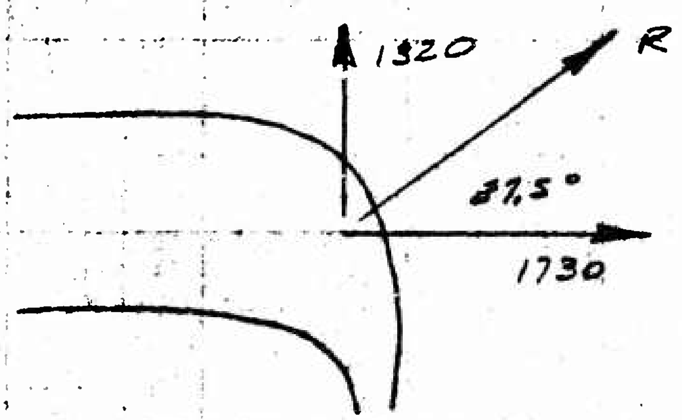
$\mathcal{F}_1 = 2520 - 14.7 \times 56 = 1{,}730\ \#$

285-0172 BLADE TIP

LOADS ON TURNING VANES - TOTAL

$F_2 = 21.8 \times 35 (1 + 1.4) = 1840^{\#}$ (LIM)

$\mathcal{F}_2 = 1840 - 14.7 \times 35 = 1320^{\#}$ (LIM)



$R = 2200^{\#}$ (LIMIT)

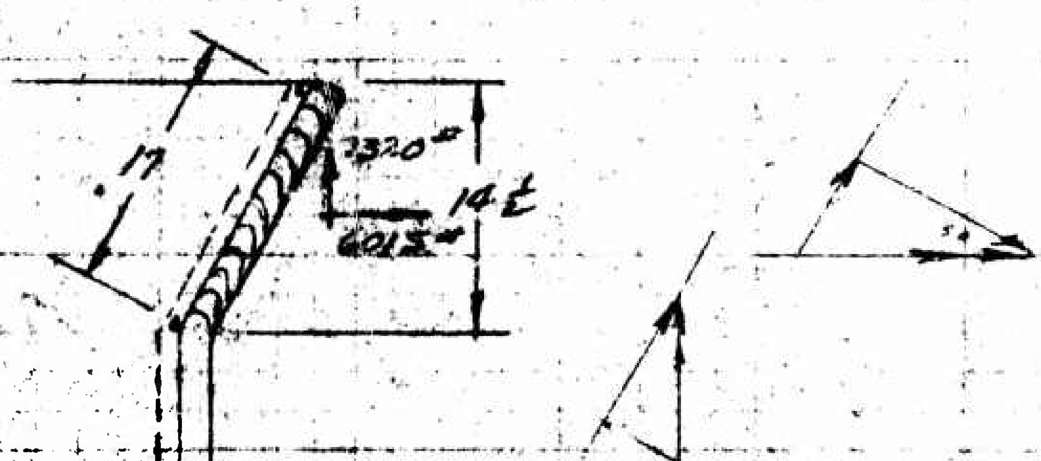
TIP WEIGHT = $5.0^{\#}$ (approx)

$P_{Press} = 1730^{\#}$ (LIM)

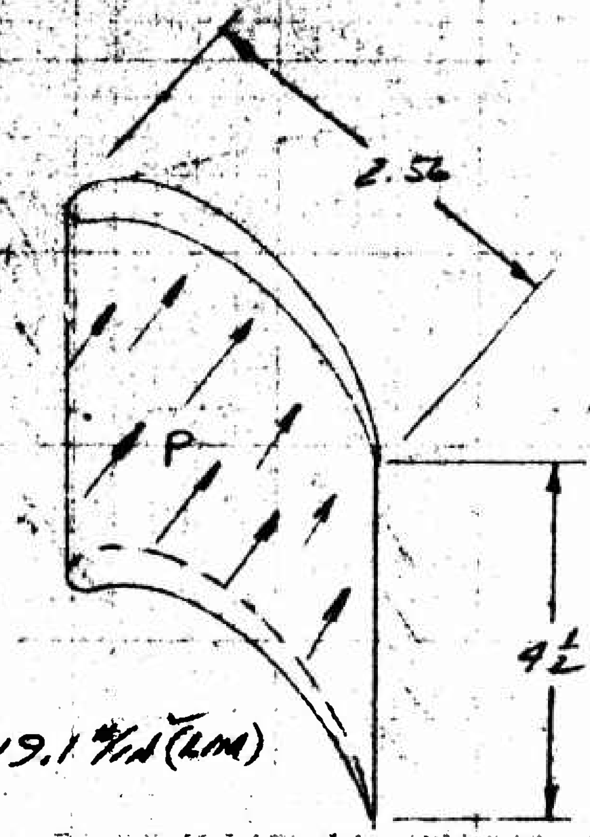
$P_{CF} = 5 \times 857 = 4285^{\#}$ (LIM) (O.R.)

$P_{CF} = 5 \times 548 = 2740^{\#}$ (LIM) (CRUISE)

$P_{TOTAL} = 1730 + 4285 = 6015^{\#}$ (LIM)



CASCADE VANE



$P = \dfrac{220}{2.56 \times 4.5} = 19.1\ \#/in^2\ (LIM)$

$Vol = 5.96\ (.025)(4.5) = .67\ IN^3$

$W = .670\ (.332) = .221\ \#$

* $C.F. = .221\ (548) = 121\ \#$ (LIM) 700 FPS

* $C.F. = .221\ (857) = 190\ \#$ LIM. O.R.

MAXIMUM DISTRIBUTED LOADING OVER DEPTH OF VANE

$w = \left[19.1 \times 2.56 + \frac{190}{4.5}\right] 1.5 = 136\ \#/IN$ ULT.

MAX. BEND. MOM. $= \dfrac{136\,(4.5)^2}{8} = 344$ IN. LBS. ULT.

* C.F. OF VANE

CASCADE VANE

ASSUMING EFFECTIVE SECTION AS TWO THICKNESSES OF .025 NAVES. 25. USE MIDLINE OF VANE AS GEOMETRY IN DETERMINING SECTION PROPERTIES

ITEM	A	Z	AZ	AZ²
1	.015	.14	.00210	.00030
2		.39	.00585	.00228
3		.56	.00840	.00471
4		.67	.01005	.00674
5		.70	.01050	.00735
6		.66	.00990	.00653
7		.58	.00870	.00505
8		.46	.00690	.00318
9		.33	.00495	.00163
10	.015	.19	.00285	.00054
11	.010	.06	.00060	.00004
Σ	.160		.07080	.03835

$\bar{Z} = \frac{.0708}{.160} = .442''$

$I_{NA} = .03835 - .160(.442)^2 = .00505\ IN.^4$

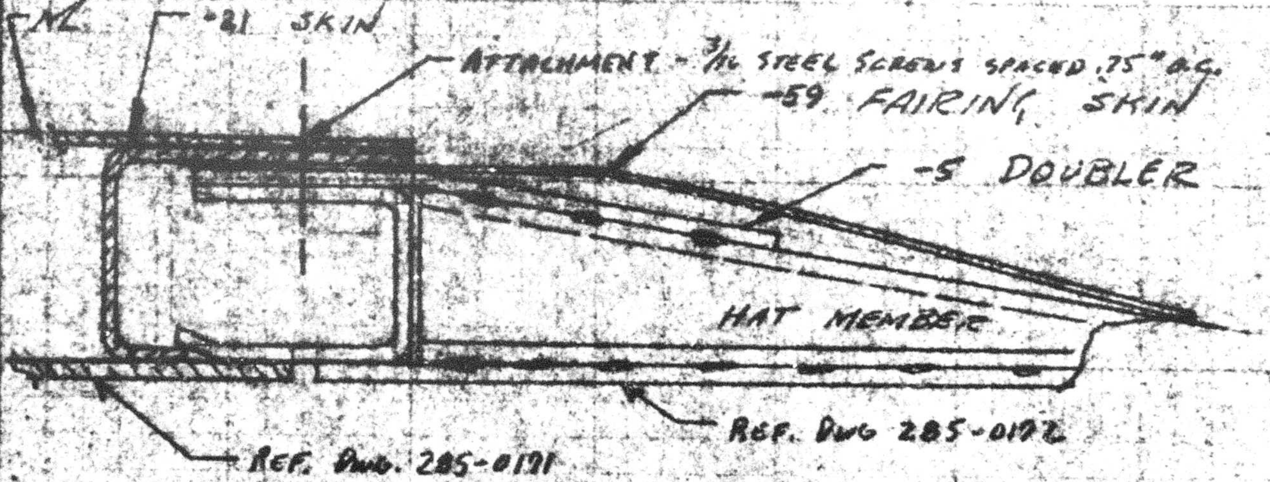
Max. BENDING MOMENT = 344 IN# ULT. FROM PREVIOUS PAGE

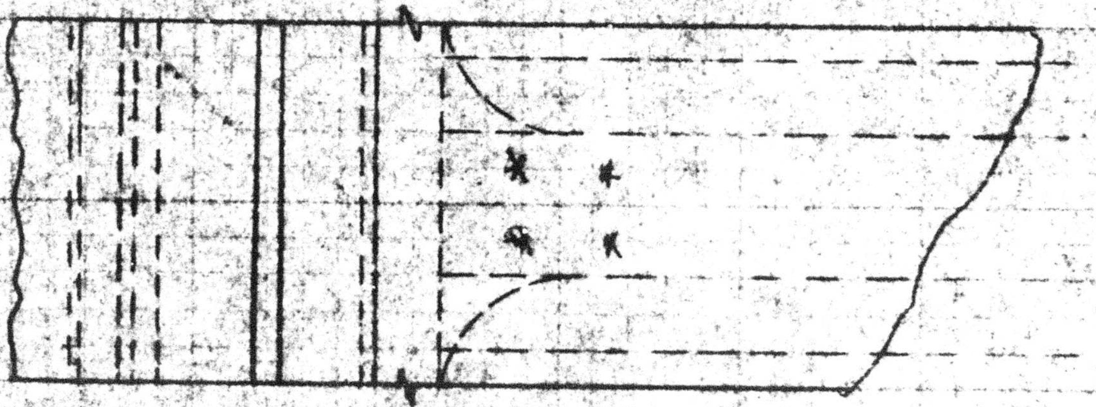
$f_b = \frac{344(.442)}{.00505} = 30100$ PSI ULT.

VANE IS SATISFACTORY

CASCADE

STRUCTURE ATTACHING TIP TO THE BLADE





ATTACHMENT LOAD

$q_{max} = (7330 + 2600)/2 \times 15 = 331$ #/in

ALLOW. $Q = .030 \times .18 \times 25000 \times .7^{*}/.75 = 1260$ #/in @ $T = 500°F$

M.S. → HIGH

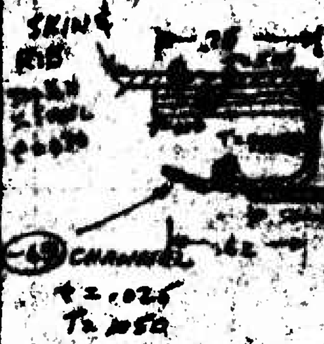
* TEMP. RED. FACTOR

BLADE TIP

TIP CASCADE

THERMAL STRESS ANALYSIS OF TIP CROSS SECTION AT ATTACH TO BLADE.

MAT'L OF CASCADE



(-33) SKIN $t = .016$

(-35) DOUBLER $t = .025$

(-3) SIDE PLATE (PRELIM. ANALYSIS SHOWED SECTION TO BE INEFFECTIVE)
$t = .025$
$T = 1400°F$

(-69) CHANNEL
$t = .026$
$T = 1050$

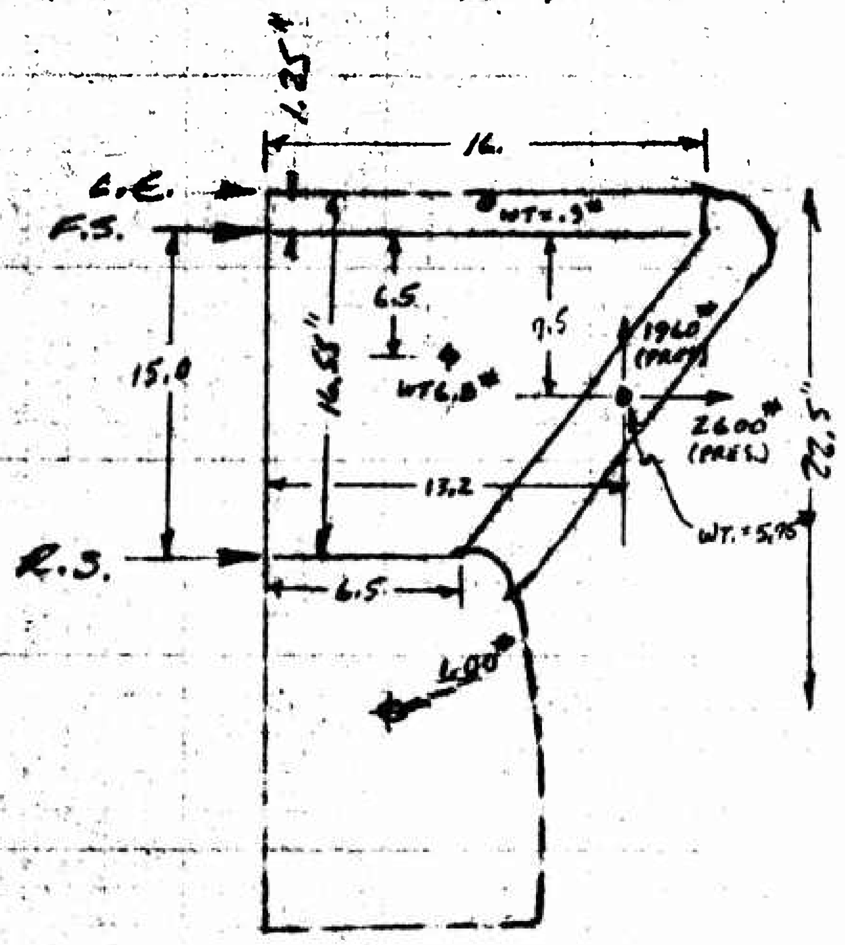
ITEM	A	ΔT	α ×10⁻⁶	E ×10⁶	f'	ΔP	f'' 10%/SA	f_RES
1	.0225	430	9.4	23.0	-93000	-2090	121500	28500
2	.0495	530	7.4	23.0	-109800	-5430		11700
3	.0083	680	7.6	22.0	-139500	1160		-18000
4	.0155	980	7.8	25.1	-192000	7970	121500	-70500
	.0958					-11650		

ITEM (4) $b/t = 22$ $F_{cy} = 72000$ psi @ 1050°F

$$M.S. = \frac{72000}{70500} - 1 = \underline{.02}$$

BLADE TIP INSTALLATION

REF. DWGS. Z85-0171 & -0192



ABOVE ARE THE WEIGHT AND CHORDWISE C.G. LOCATIONS OF THE BLADE TIP ITEMS AND THE LOCATION AND MAGNITUDE OF CASCADE PRESSURE LOADS.

ITEM	WT	ULT. INERTIA g's	ULT. FORCE
CASCADE	5.75	1275	7330
PRESSURE			2600
MAIN SEGMENT	6.8	1275	8680
TRAILING EDGE	1.0	1275	1275
LEADING EDGE	.9	1275	1150

TIP MAIN SEGMENT

SKIN

SKIN SHEAR @ REAR EDGE $= .5(2670 + 7330) + \frac{6.5}{15}(8680) + 1980\left(\frac{13.2}{15.0}\right)$
$= 10460$ LBS. ULT.

SHEAR / SKIN $= \frac{10460}{2} = 5230^{\#}$ $\quad q_s = 5230/6.5 = 805$ #/IN.

SKIN IS .016 1/2 HARD STAINLESS STEEL @ TEMP. OF 450°F

TEMP. REDUCTION FACTOR = .73

$F_{su} = 80000 \times .73 = 58400$ psi REF. 1

$f_s = 805/.016 = 50300$ psi

$$M.S. = \frac{58400}{50300} - 1 = \underline{\underline{.16}}$$

AFT WEB

$q_{max} = 805 + \frac{1275}{2 \times 6.5} = 903$ #/IN.

WEB IS .020 1/2 H. STAINLESS

$F_{su} = 58400$ psi @ 450°F REF. 1

$f_s = 903/.020 = 45000$ psi

$$M.S. = \frac{58400}{45000} - 1 = \underline{\underline{.30}}$$

ATTACH TO SPAR

AFT SPAR LOAD $= 10460 + 1275 = 11735^{\#}$ ULT.

ATTACHMENT IS WITH (3) 5/16 STEEL BOLTS (NAS 464 P5)

LOAD PER BOLT $= 11735/3 = 3910^{\#}$

t OF WEB & DOUBLER $= .020 + .051 = .071$ IN.

$f_{br} = 3910/(.071)(.313) = 176000$ psi

F_{bru} @ 500°F $= 300000 \times .70 = 210000$ psi REF. 1

$$M.S. = \frac{210000}{176500} - 1 = \underline{\underline{.19}}$$

ANALYSIS
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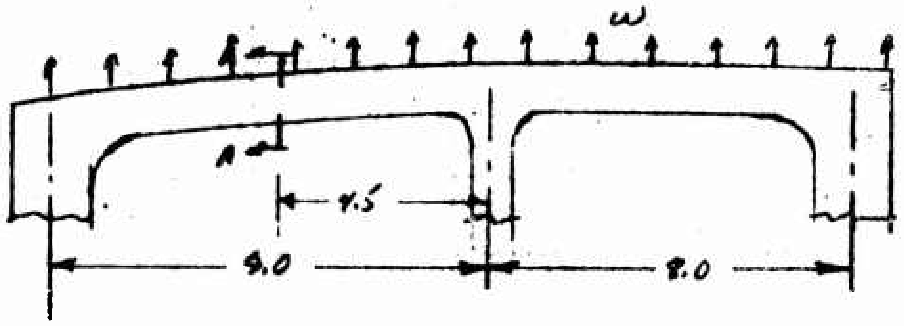
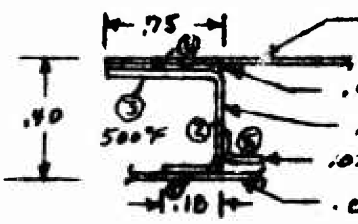
BLADE TIP

TIP MAIN SEGMENT

OUTB'D RIB



SECTION A-A CRITICAL SECTION



THERMAL STRESSES

ITEM	A	ΔT	$\alpha \times 10^{-6}$	$E \times 10^{6}$	f'	ΔP	$f'' = \frac{\Sigma \Delta P}{\Sigma A}$	$f_{RES.}$
1	.0054	850	7.8	27	-177000	-955	117500	-59500
2	.0066	610	7.8	28	-133000	-875	↓	-15500
3	.0150	430	7.8	30	-101000	-1520		16500
4	.0195	370	9.4	25	-87000	-1700		30500
5	.0080	800	7.8	27	-169500	-1350	117500	-52000
	.0545					-6400		

PRESSURE STRESSES

SECTION PROPERTIES

ITEM	A	z	Az	Az²
1	.0054	0	0	0
2	.0066	.200	.00132	.000264
3	.0150	.364	.00546	.001986
4	.0195	.387	.00755	.00292
5	.0080	.045	.00036	.000016
Σ	.0545		.01469	.00519

$\bar{z} = .01469/.0545 = .269$

$I_{NA} = .00519 - .0545(.269)^2 = .00124 \text{ IN.}^4$

$w \doteq 41.2 \times 1.5 = 61.8 \text{ \#/IN ULT.}$

$M_{OM.} = \frac{wL^2}{24} = 61.8(9.0)^2/24 = 208 \text{ in-\#}$

$f_b = 208(.269)/.00124 = 45600 \text{ PSI}$

COMBINED STRESS ON ITEM 1 = 59500 + 45600 = 105100 PSI

FOR $b/t = 9$ @ $T = 920°$ $F_{cc} = 109000 \times .97 = 106000$ PSI REF. SECT. 2.

$M.S. = \frac{106000}{105100} - 1 = \underline{\underline{.01}}$

5.2.6 Blade Transition Section

5.2.6.1 Description

The blade transition section is located between the strap-to-spar attachment and the blade constant section, Station 73 to 91. The blade transition section covers the duct transition section and ties to the duct at Station 90 as shown in Drawing 285-0195. The duct transition section is analysed in Section 5.2.10.

The blade transition section is made in three segments approximately 6 inches in length and are joined by electroformed nickel flexures. The outboard segment skins and webs are made from corr. res. steel, type 301 1/2 H and the primary method of attachment is with spotwelds. The center and inboard segment skins and webs are made from 6AL 4V titanium alloy and the primary method of attachment is with monel rivets. The segment tie to the spars is with four 1/4 inch steel bolts, two to each spar.

The blade transition section is designed to carry torque and chordwise shears but not to carry flapwise bending moments therefore not adding to the flapwise bending stiffness of the blade. The flexures must be as flexible as possible for absorbing the differences in deflection between segments and structurally satisfactory to transfer torque and chordwise shear.

ANALYSIS

PREPARED BY J. NEEDHAM 4/12/60

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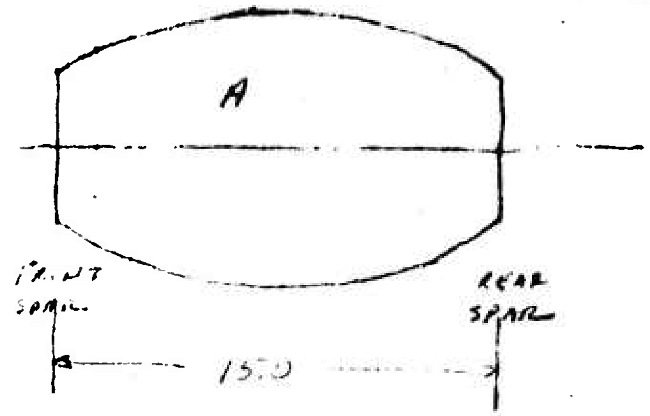
BLADE TRANSITION SECTION

TORQUE AREA

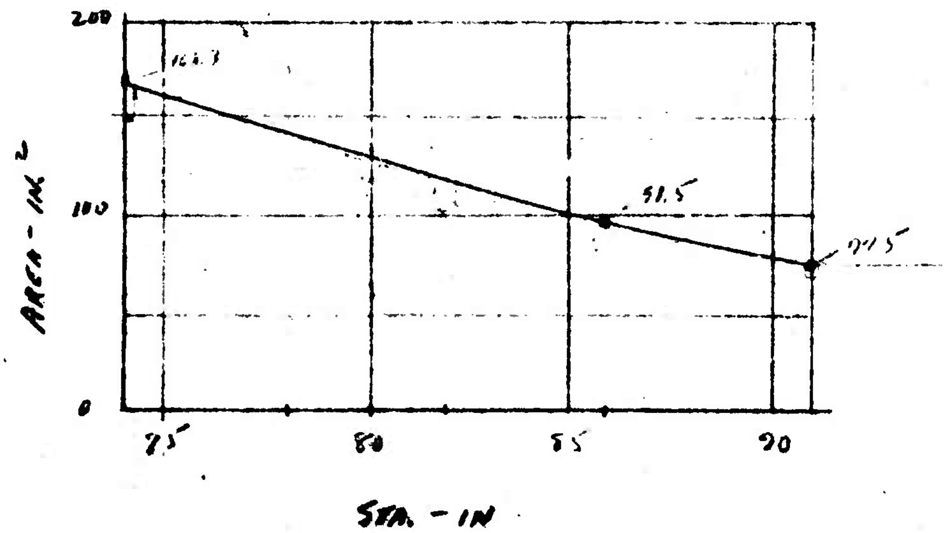
REF. DWG. 285-0138 FOR DIMENSIONS.



$$A_{74} = \frac{3.0}{2}\left[9.15 + 2\times 11.7 + 2\times 13.05 + 2\times 12.60 + 2\times 10.45 + 7.45\right] = 168.3 \text{ IN}^2$$

$$A_{86} = 98.5 \text{ IN}^2$$

$$A_{91} = 77.5 \text{ IN}^2$$



BLADE TRANSITION SECTION

MAX. SHEAR FLOWS STN. 74 TO 91

WEIGHTED FATIGUE COND. — LIMIT VALUES REDUCED TO:

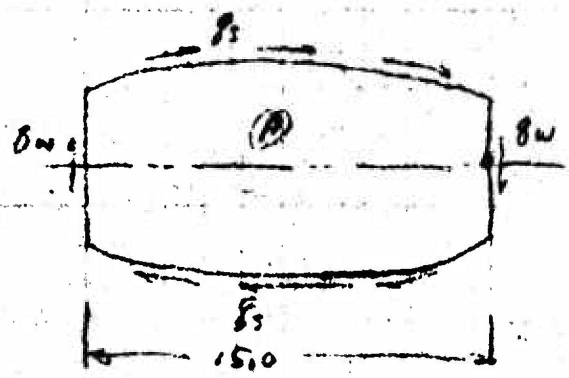
STEADY SHEAR = 200# — CYC. SHEAR = ±520 ±381#

" TORQUE = 13100"# — CYC TORQUE = ±9900"# ±7320

2 ½ MANEUVER

STEADY SHEAR = 100# — CYC SHEAR = ±1550#

" TORQUE = 23870"# — " TORQUE = 0



$$q_s = \frac{\text{SHEAR}}{2 \times 15} + \frac{\text{TORQUE}}{2(A)}$$

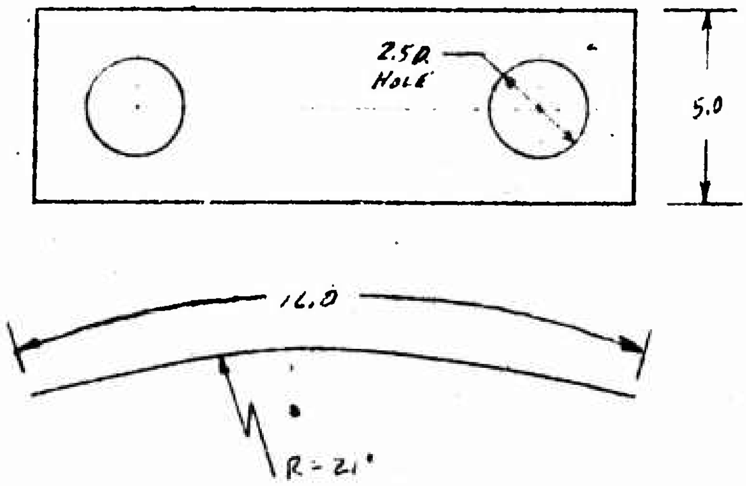
$$q_w = \frac{\text{TORQUE}}{2(A)}$$

STA	2(A)		WEIGHTED FATIGUE COND			2 ½ MANEUVER COND		
			S/30	T/2(A)	q_s	S/30	T/2(A)	q_s
74	336	CYC	*19.3	24.5	46.8	51.7	0	51.7
		STEADY	6.7	39.0	45.7	3.3	71.0	74.3
78	286	CYC	17.3	34.6	51.9	51.7	0	51.7
		STEADY	6.7	45.8	52.5	3.3	83.5	86.8
82	238	CYC	17.3	41.6	58.9	51.7	0	51.7
		STEADY	6.7	55.0	61.7	3.3	100.3	103.6
86	197	CYC	17.3 (12.1)	50.3 ([illegible])	67.6	51.7	0	51.7
		STEADY	6.7 (5.0)	66.5 ([illegible])	73.2	3.3	121.2	124.5
90			12.6	38.1				
			6.7	50.4				

* CAN BE REDUCED BY (380/520) = .74

△ NOTE: THE CYCLIC CHORDWISE SHEAR AND TORQUE WERE REDUCED. THE TRANSITION STRUCTURE WAS DESIGNED PRIMARILY BY THE ORIGINAL LOADING.

SKIN SHEAR PANEL – STA. 74 TO 80



STRESS CONCENTRATION AT EDGE OF HOLES (REF. NACA TN 984) REF. 14

FOR CIRCULAR HOLE NOT REINFORCED

STRESS CONCENTRATION FACTOR $F = 2.00 + 4.21\beta - 3.46\beta^2 + 12.50\beta^3$

$\beta = \frac{\text{HOLE DIA.}}{\text{DEPTH OF BEAM}}$ GOOD FOR $\beta = 0$ TO .70

$\beta = \frac{2.5}{5.0} = .50 \quad \beta^2 = .250 \quad \beta^3 = .125$

$F = 2.000 + 4.21(.50) - 3.46(.250) + 12.50(.125) = 4.80$

f_s (ON SOLID WEB) $= 2625 \pm 2595$ (WEIGHTED FATIGUE COND.)

$f_{s_{MAX}} = 4.80[2625 \pm 2595] = 12{,}600 \pm 12{,}440$

MAX. f_s BASED ON NET AREA

$f_{s_{MAX}} = (2625 \pm 2595)\left(\frac{5.0}{5-2.5}\right) = 5250 \pm 5190$ psi

SKIN SHEAR PANEL - STA. 94 TO 80

PANEL WIDTH = 5.0" LENGTH ≅ 16." RADIUS ≅ 14" @ STA 80

MAT'L - TITANIUM $t = .032$

CURVED PANEL ANALYSIS

$h/d = \frac{16.0}{5} = 3.2$ $Z = \frac{.954(5.0)^2}{14(.032)} = 53.3$ $K_s = 16.5$

$F_{scr}/\eta = 16.5 \times 15 \times 10^6 \left(\frac{.032}{5.0}\right)^2 = 10100$ PSI $= F_{scr}$

WEIGHTED FATIGUE COND.

$q_s = 51.4 \pm 46.4$ #/IN

$f_s = \frac{51.4 \pm 46.4}{.032} = 1610 \pm 1450$ PSI

FOR STRESS CONCENTRATION FACTOR = 4.80 (REF NACA TN 984) REF 14

$f_s = (1610 \pm 1450)4.8 = 7700 \pm 6950$ PSI

PANEL IS SATISFACTORY

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

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ANALYSIS

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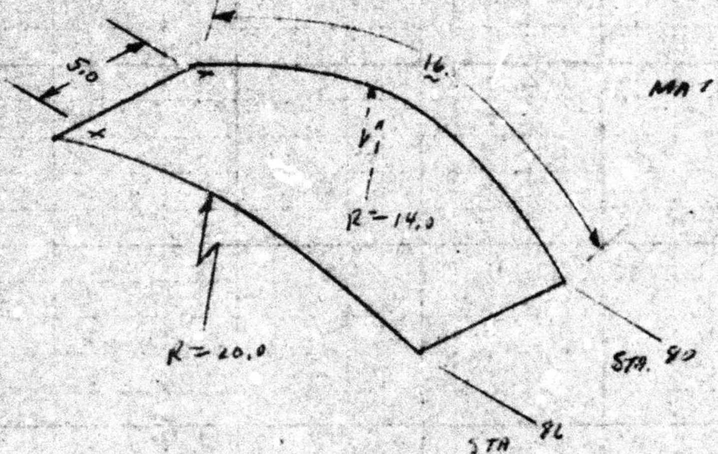
BLADE TRANSITION SECTION

SKIN SHEAR - PANEL 80 TO 86



MAT'L - .032 TITANIUM (6AL-4V)

$$Z = .954 \frac{a^2}{Rt} = \frac{.954(5.0)^2}{17.0(.030)} = 46.8 \qquad K_s = 15.5$$

$$F_{scr}/\eta = 15.5 \times 15 \times 10^6 \left(\frac{.032}{5.0}\right)^2 = 9500 \text{ psi}$$

$$q_{s_{max}} = 73.2 \pm 62.9$$

$$f_s = \frac{73.2 \pm 62.9}{.030} = 2440 \pm 2100 \text{ psi}$$

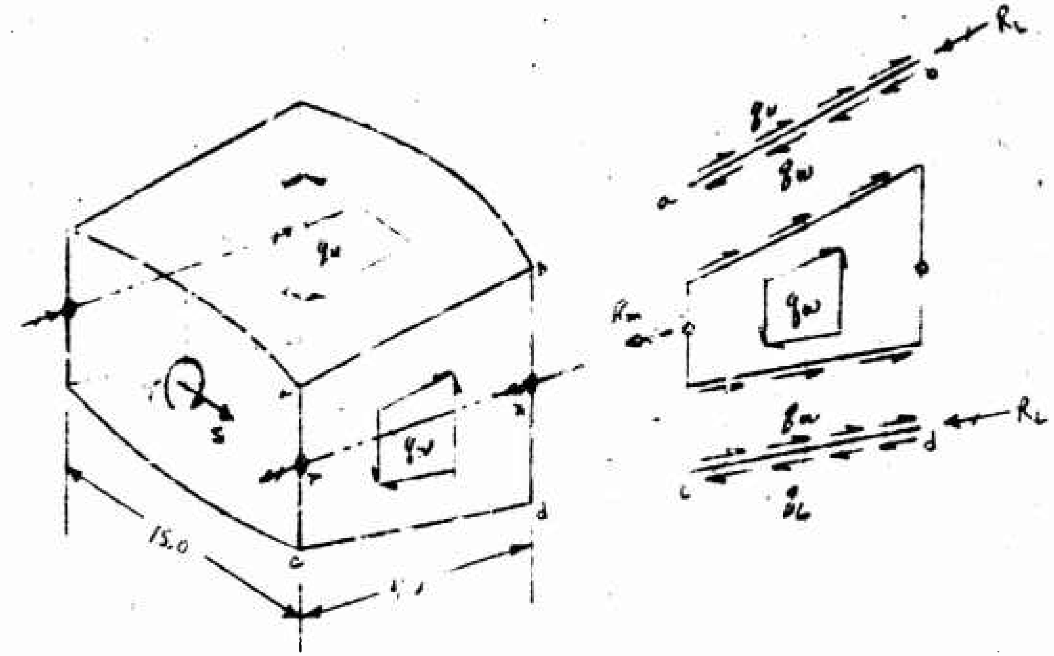
$$f_{s_{max}} = 4540 \times 1.5 = 6800 \text{ psi ULT.}$$

NON-BUCKLING AT ULT. SHEAR STRESS.

9704

BLADE TRANSITION SECTION

WEB SHEAR DISTRIBUTION



$$q_u = \frac{T}{2A} + \frac{S_1}{2\times 15}$$

$$q_w = \frac{T}{2A}$$

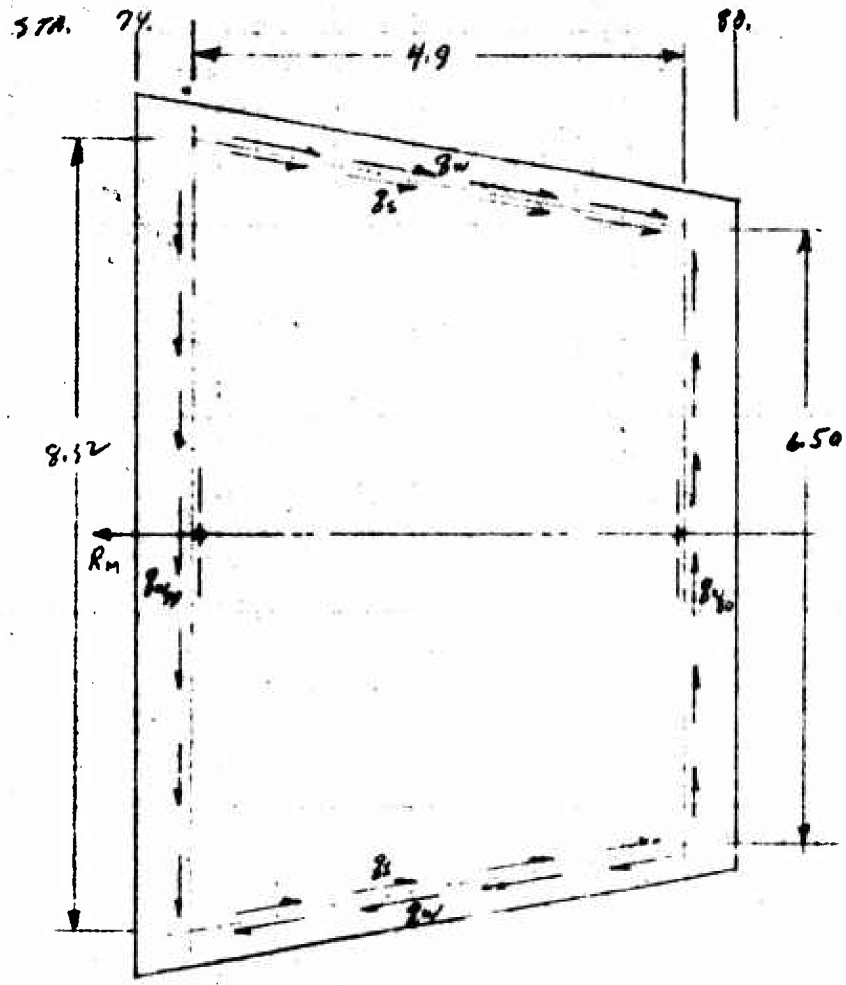
$$q_L = \frac{T}{2A} - \frac{S}{30}$$

$$R_m = 4.9\left[q_u - q_L\right] = 4.9\left[\frac{2S}{30}\right] \approx .3[illegible]\,S$$

BLADE TRANSITION SECTION

SEGMENT WEBS

STA. 74 TO 80 FRONT WEB



LET q_{s_1} AVG. SHEAR ... STA. 74 & 80

$q_{w_{cyc}} = \pm 33.8$ #/IN. $\qquad$ $q_{w_{STEADY}} = 44.7$ #/IN.

$q_{w_{80}} = \pm 33.8 \left(\frac{8.32}{6.50}\right) = \pm 43.3$ #/IN. $\qquad$ $q_{w_{80}} = 57.2$ #/IN.

$q_{w_{74}} = \pm 33.8 \left(\frac{6.50}{8.32}\right) = \pm 26.4$ #/IN. $\qquad$ $q_{w_{74}} = 34.9$ #/IN.

$q_{s_{cyc}} = \pm 12.6$ #/IN $\qquad$ $q_{s_{STEADY}} = 6.7$ #/IN.

$R_{M_{cyc}} = .327 (\pm 380) = \pm 124$ #

SEGMENT WEBS CONT'D

STA. 74 TO 80 - FRONT WEB - MAT'L TITANIUM ALLOY (6AL-4V)

PANEL SIZE $\frac{6.9+5.9}{2} = 7.41$ 7.41 X 4.9 t = .030 (TITANIUM)

$\frac{a}{h} = \frac{4.9}{7.41} = .66$ $K_S = 6.45$

$F_{scr}/n = 6.45 \times 15 \times 10^6 \left(\frac{.030}{4.9}\right)^2 = 3630$ psi

$q_s = 44.7 + 6.7 \pm [33.8 \pm 12.6] = 51.4 \pm 46.4$ #/in.

$f_s = \frac{51.4 \pm 46.4}{.03} = 1710 \pm 1550$

$f_{s_{max}}$ 3260 psi

t = .036

$F_{scr}/n = 6.45 \times 15 \times 10^6 \left(\frac{.036}{4.9}\right)^2 = 5220$ psi

$f_s = \frac{51.4 \pm 46.4}{.036} = 1430 \pm 1290$

$f_{s_{max}}$ 2720 psi

t = .032 (USED IN BLADE)

$F_{scr}/n = 6.45 \times 15 \times 10^6 \left(\frac{.032}{4.9}\right)^2 = 4130$ psi $= F_{scr}$

$f_s = \frac{51.4 \pm 46.4}{.032} = 1610 \pm 1450$ psi

$f_{s_{MAX}} = 3060$ psi LIM.

M.S. $= \frac{4130}{3060} - 1 =$ .35

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS
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MODEL 285 REPORT NO. 285-13 PAGE 5.2.6.10

BLADE TRANSITION SECTION

ATTACHMENT OF SEGMENT TO SPARS

SEGMENT WEIGHT

LENGTH OF SEGMENT = 6.0"

CROSS-SECTIONAL AREA:

$\cong .032 [2 \times 16 + 2 \times 9.0] + 4(.036) = 1.744 \text{ in}^2$

VOL. = 5 × 1.744 = 8.73 CU. IN.

WT. = .160 × 8.73 = 1.40 #

WT. ELECTRO-FORM NICKEL BUSHINGS

$\cong [1.5 \times .015 + 1.4 \times .035]\ 54 \times .32 = 1.24$ #

TOTAL WT. OF SEGMENT = 1.40 + 1.24 = 2.64 #

LET = 3.0 # (14% INCREASE)

C.F. LOAD FACTOR @ STA. 80

NORMAL = 132 OVER REV. = 208

$P_N = 132 \times 3 = 394$ # LIM.

$P_{OV} = 208 \times 3 = 624$ # LIM.

LET 55% OF LOAD ON ONE BOLT

$P_{B_{OV}} = .55 \times 624 \times 1.5 = 515$ # ULT

1/4" BOLT BRG IN .032 TITANIUM

$f_{br} = \frac{515}{.25 \times .032} = 64{,}400$ psi $F_{br} = 244\,000 \times .74 = 180\,000$ psi @ 450°F REF. 1

LOAD ON BOLT FROM CYCLIC SHEAR FLOW.

$P = \pm 124$ # $f_{br} = \frac{\pm 124}{.008} = \pm 15\,500$ psi

9704

ANALYSIS
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BLADE TRANSITION SECTION

FLEXURE ANALYSIS

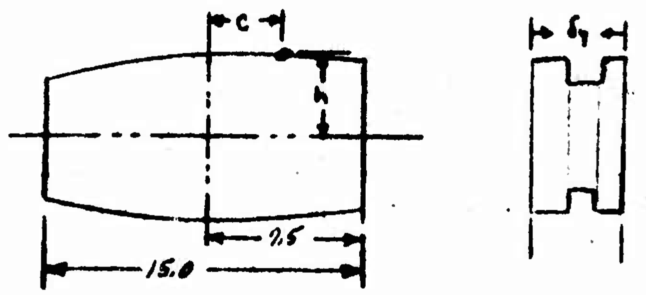
REAR SPAR STRESSES – REF. SECT. 5.2.2.

LIMIT STRESSES FOR WEIGHTED FATIGUE CONDITION.

STA.	STEADY f_t	CYC. BEND. $\pm f_b$	CYC. AXIAL $\pm f_c$	C	$\left(\frac{f_b}{c}\right)=\left(\frac{M}{I}\right)$
74	32500	± 4900	± 3130	1.62	± 3020
90	44300	± 5160	± 3830	1.59	± 3250
120	43000	± 5430	± 3120	1.52	± 3570

DEFLECTIONS AND ROTATIONS ARE COMPUTED ON THE FOLLOWING PAGES 5.2.6.12 & 13

THE CYCLIC DEFLECTION (δ_y) TO BE ABSORBED BY THE FLEXURE AT ANY POINT (C,h) ON THE FLEXURE IS AS FOLLOWS:



STA. 74.12

$$\delta_{y\,cyc.} = \pm .000088\,c \pm .00073\,h$$

STA. 80.12

$$\delta_{y\,cyc} = \pm .000186\,c \pm .00123\,h$$

STA. 86.12

$$\delta_{y\,cyc} = \pm .000189\,c \pm .00114\,h$$

STA. 91.0

$$\delta_{y\,cyc} = \pm .000311\,c \pm .00166\,h$$

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ANALYSIS

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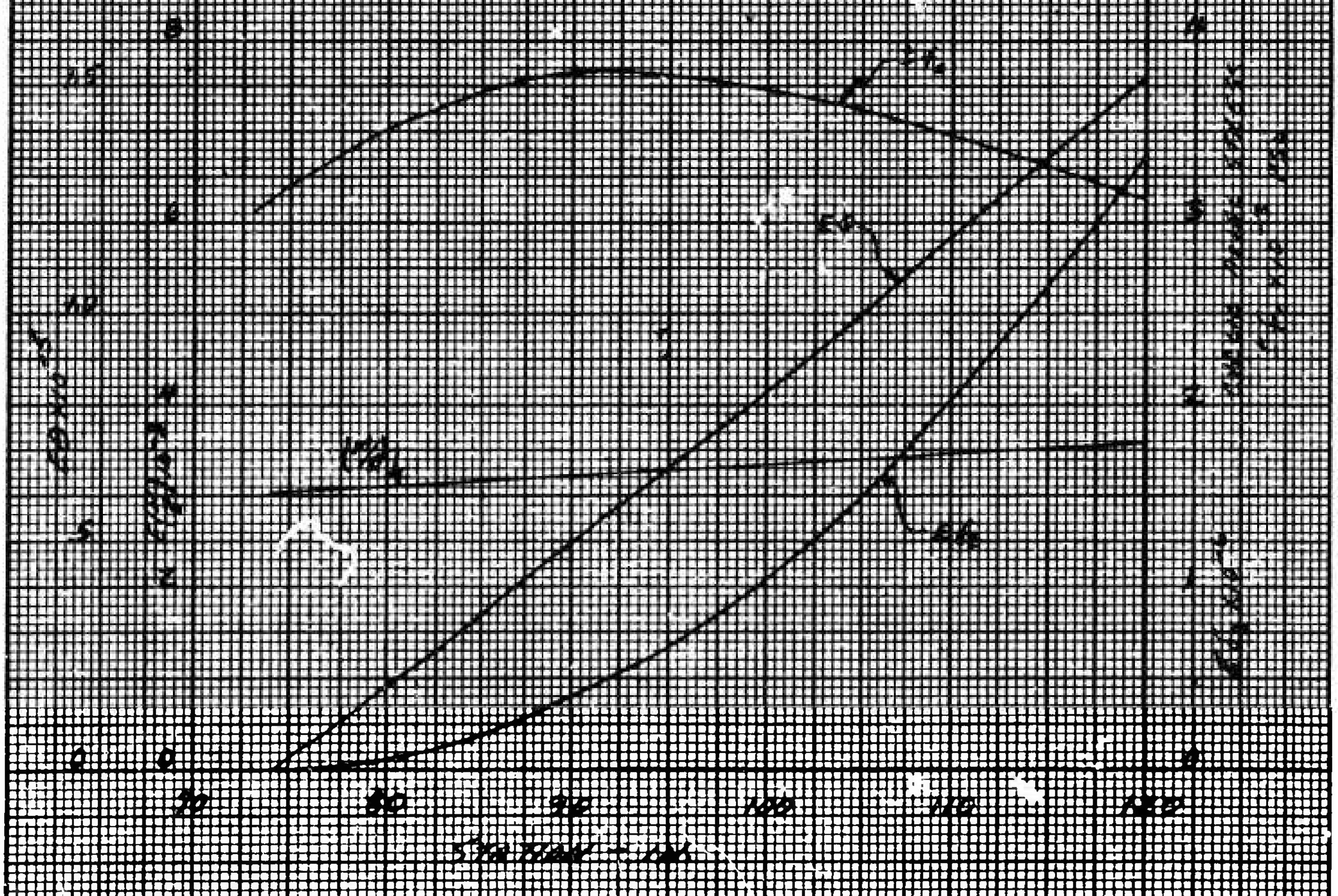
BLADE [illegible] SECTION

[illegible]



FORM NO. 9.26

ALBANENE NO. 195T

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS

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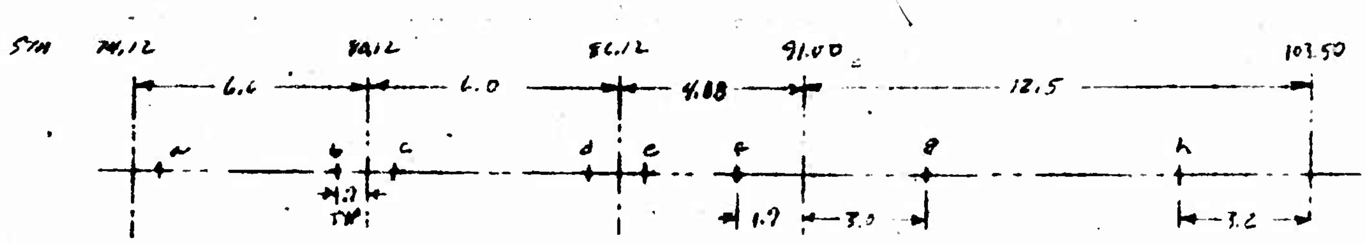
BLADE TRANSITION SECTION

LOCATION OF FLEXURES AND ATTACH OF SEGMENTS IN TRANSITION AREA.



a THRU h BOLTS ATTACHING SEGMENTS TO SPAR

FOR WEIGHTED FATIGUE CONDITION — SLOPE @ FLEXURES FOR FLAP. MOM.

① BOLT	② STA.	③ ε f e in^{-6}	④ δ_x	⑤ MEMBER	⑥ LENGTH MEMB	⑦ SLOPE ④÷⑥	⑧ NET SLOPE @ FLEX.	STA
a	74.8	0	0				±.00073	74.12
				ab	4.6	.000926		
b	79.4	.05	.00334					
				bc			±.00123	80.12
c	80.8	.075	.00500					
				cd	4.6	.001935		
d	85.4	.21	.0142					
				de			±.00114	86.12
e	86.8	.26	.0173					
				ef	2.4	.00310		
f	87.3	.37	.0247					
				fg			±.00166	91.00
g	94.0	.62	.0417					
				gh	6.3	.00476		
h	100.3	1.07	.0714					

REAR SPAR CYCLIC AXIAL DEFLECTION — CHORDWISE MOM.

STA. 74.12 $\delta_x = \frac{3300(3.0)}{15 \times 10^6} = \pm .00066''$

STA 80.12 $\delta_x = \frac{3500(6.0)}{15 \times 10^6} = \pm .00140$

STA 86.12 $\delta_x = \frac{3800(5.6)}{15 \times 10^6} = \pm .00142''$

STA 91.00 $\delta_x = \frac{3800(9.2)}{15 \times 10^6} = \pm .00233''$

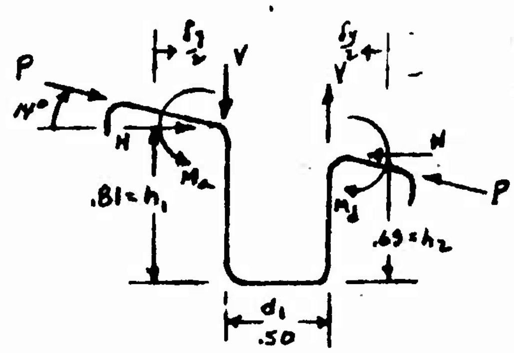
9704

ANALYSIS
PREPARED BY J. NEEDHAM 6/3/60
CHECKED BY

BLADE TRANSITION SECTION

FLEXURE ANALYSIS

THE FLEXURE AT STA. 80.12 IS CRITICAL FOR CYCLIC FLAPWISE BENDING. THE CRITICAL SECTION OF THE FLEXURE IS SHOWN BELOW. SEE SKETCH PG. 5.2.6.11 AT $c = 1.0$, $h = 5.15$



$P = H/\cos 14° = 1.030\,H$

$V = H\,(h_1 - h_2)/d_1 = \frac{.12\,H}{.5} = .24\,H$

WHERE

$M_a = M_d = \frac{h_1}{2} H = .405\,H$

THICKNESS IS CONSTANT $= .013$ IN.

FROM AN ELASTIC ENERGY SOLUTION

$$EI\delta_y = \frac{H}{3}\left[h_1^3 - .75h_1^2h_2 - .75h_1h_2^2 + h_2^3\right] + \frac{d_1 H}{3}\left[.25h_1^2 - .50h_1h_2 + h_2^2\right]$$

$$= .1367\,H$$

$$\text{MAX } \delta_{y_{cyc}} = \pm .000186\,(1.0) \pm .00123\,(5.15) = \pm .0066$$

$$E = 30 \times 10^6 \qquad I = 1.0\,(.013)^3/12 = .183 \times 10^{-6}$$

$$H = \frac{30 \times 10^6 \times .183 \times 10^{-6}\,(\pm .0066)}{.1367} = \pm .265 \text{ LBS.}$$

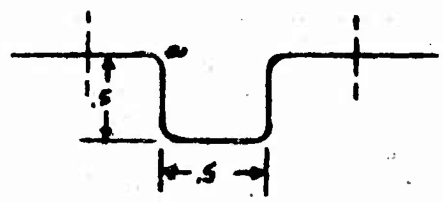
$$M_a = .405\,(\pm .265) = \pm .108 \text{ IN. LBS.}$$

$$f_b = \frac{\pm .108 \times 6}{(.013)^2} = \pm 3830 \text{ psi}$$

THE FLEXURE IS SATISFACTORY.

FLEXURE ANALYSIS

CROSS-SECTION OF FLEXURE AT SPAR ℄.



REF. DWG 285-013B SECT. F-F

CROSS-SECTION CONSISTS OF OVERLAPED FLEXURES SPOTWELDED TOGETHER
NOMINAL COMBINED $t = .041$ IN.

FLEXURE AT STA. 86.12 IS CRITICAL

CYCLIC DEFLECTION

$$\delta_y = \pm.00142 \pm.00114(.8) = \pm.0023 \text{ IN.}$$

CYCLIC CHORDWISE SHEAR FLOW $q_{s_c} = \pm 12.6$ #/IN.

FROM AN ELASTIC LOAD ANALYSIS, THE FLEXURE BENDING STRESS AT POINT a IS

FOR DEFL. $f_{b_b} = 72.1\, \delta_y\, t \times 10^6$ FOR SHEAR $f_{b_s} = \dfrac{.594\, q_s}{d\, t^2}$

CYCLIC DEFL. STRESS $f_{b_b} = 72.1(\pm.0023)(.041)10^6 = \pm 6800$ PSI

CYCLIC CHORDWISE SHEAR $f_{b_s} = \dfrac{.594(\pm 12.6)}{1.6\,(.041)^2} = \pm 2800$ PSI
(WHERE d = DEPTH = 1.6")

COMBINED CYCLIC BENDING STRESS AT POINT 'a'

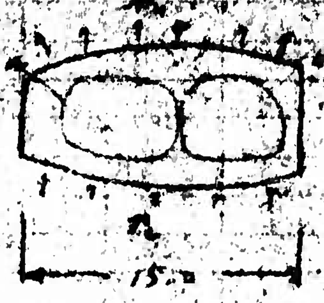
$$= \pm 6800 \pm 2800 = \pm 9600 \text{ PSI}$$

ALLOWABLE CYCLIC BENDING STRESS OF ELECTROFOAM NICKEL
$= \pm 12500$ PSI

$$M.S. = \frac{12500}{9600} - 1 = \underline{\underline{.30}}$$

FLEXURE ANALYSIS

FLEXURE OF A FRAME TO SUPPORT PRESSURE LOADS.

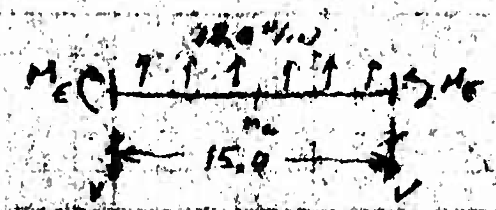


P_R (AVG.) = 3.0 psi (CONSERVATIVE DUE TO VENT HOLES)

SPACING OF RIB FLEXURES = 6.0

$w = 3.0 \times 6.0 = 18.0$ #/IN/CHORD IN.

ASSUME A BEAM FIXED AT a & b NEGLECT CURVATURE (CONSERV.)

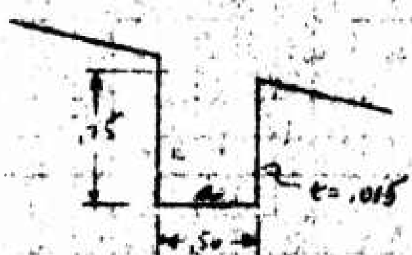


$M_E = \frac{18(15)^2}{12} = 338$ in#

$M_c = \frac{18(15)^2}{24} = 169$ in#

$V = \frac{15(18.0)}{2} = 135$ #

MINIMUM CROSS-SECTION IS AT M_c AND IS SHOWN BELOW.



LET $I \cong 2(.5)(.015)(.375)^2 + \frac{2(.015)(.75)^3}{12}$

$= .00211 + .00112 = .00323$ in^4

$f_{b_c} = \frac{169(.375)}{.00323} = 19600$ psi COMP.

$k = \frac{b}{t} = \frac{.500}{.015} = 33.3$

$F_{cr}/\eta = 3.62 \times 30 \times 10^6 \left(\frac{.015}{.500}\right)^2 = 97600$ psi

$F_{cc} \cong F_{cy} = 40000$ psi @ 600 °F

$M.S. = \frac{40000}{19600} - 1 = \underline{1.04}$

5.2.7 STRUCTURE STA. 63 TO 73

THE BLADE STRUCTURE BETWEEN STA. 63 AND 73 IS THE REGION IN WHICH THE STRAPS ARE ATTACHED TO THE SPARS. THE STRUCTURE CONSISTS OF RIBS AT STA. 63 AND 73 AND WEB AND SKIN THAT COMPLETE A TORQUE CELL. THE RIBS ARE MADE FROM 4340 STEEL H.T. [illegible]. THE SKIN AND WEBS ARE MADE FROM .071 2024-T81 ALUM. ALLOY ALCLAD.

THE PURPOSE OF BLADE STRUCTURE STA. 63 TO 73 IS TO PROVIDE STRUCTURAL CONTINUITY AT THE ATTACHMENT OF THE STRAPS TO THE SPARS. THE STRUCTURE REDISTRIBUTES THE UNBALANCED LOADS AND MOMENTS AT THE TIE OF THE STRAPS TO SPARS. THE RIB AT STA. 73 IS ALSO A TIE BETWEEN SPARS FOR THE LOAD INDUCED BY THE SPARS BEING BENT AT STA. 73. THE ELEVATED TEMPERATURES FOR THE STRUCTURE ARE SKINS, $T = 275°F$, WEBS $T = 250°F$ AND RIBS $T = 300°F$ APPROX.

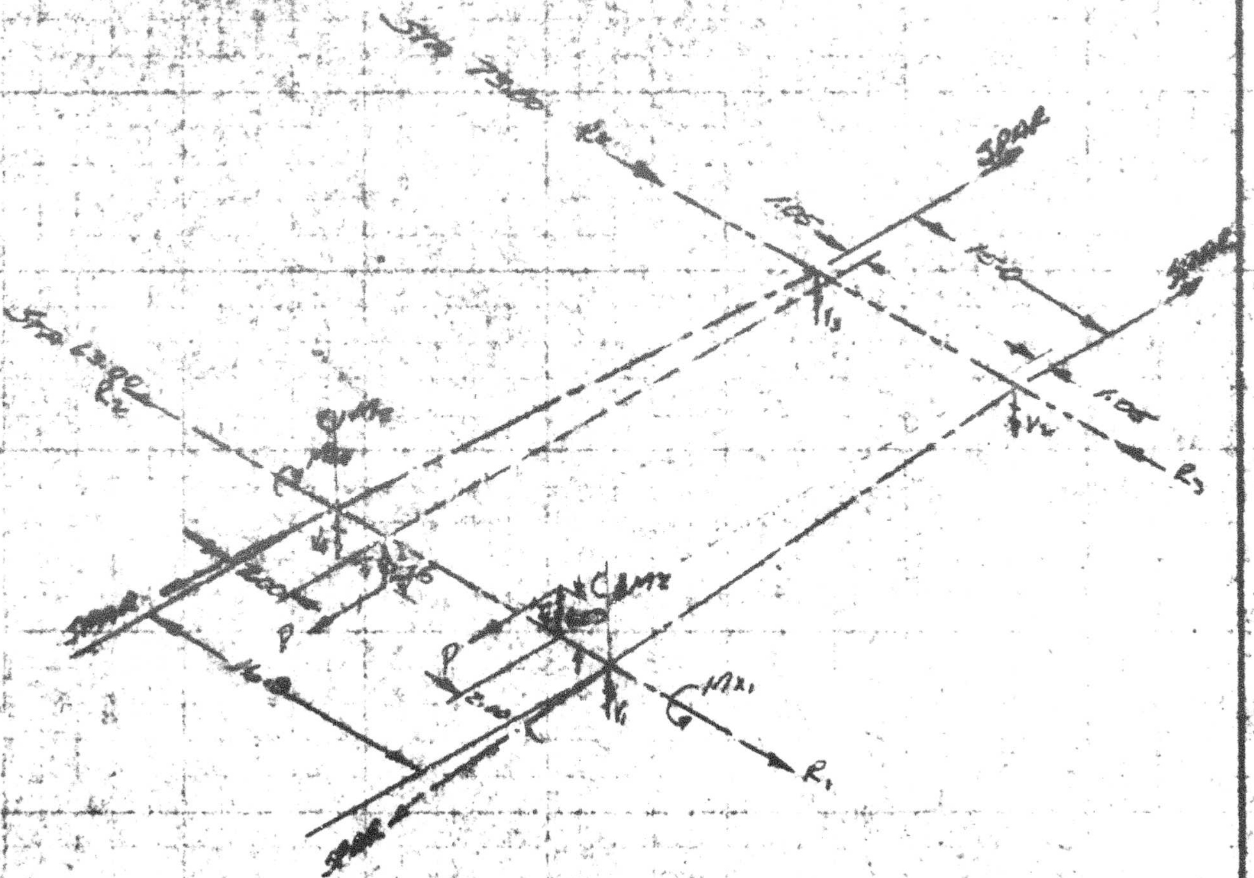
THE FOLLOWING ARE UNCORRECTED CHANGES IN THE ANALYSIS

1) THE BLADE WAS BALANCED ABOUT THE FEATHERING AXIS PRODUCING EQUAL C.F. LOADS IN THE STRAPS AND THE BLADE IS NOW BALANCED ABOUT THE 25% CHORD. THIS DISTRIBUTES THE C.F. LOAD, 52% TO FWD. STRAP AND 48% TO AFT STRAP. THIS ALSO CAUSES CHANGES IN LOADS REDISTRIBUTED BY THE STRUCTURE.

2) THERE HAVE BEEN SMALL CHANGES IN GEOMETRY.

BLADE STRUCTURE

FLAT PITCH OVERREV



STRAP TENSION FOR FLAT PITCH OVERREV IS 79,000 LBS* (REF SECTION 5.2.3)

SO P = 79,000 LBS

$M_{X_1} = 79{,}000 \times 1.50 = 118{,}500$ IN LBS

$M_{X_2} = 79{,}000 \times 1.25 = 98{,}750$ IN LBS

$T_2 = T_1$ = P × ANGLE OF STRAP WRAP (γ) DUE TO PITCH CHANGE

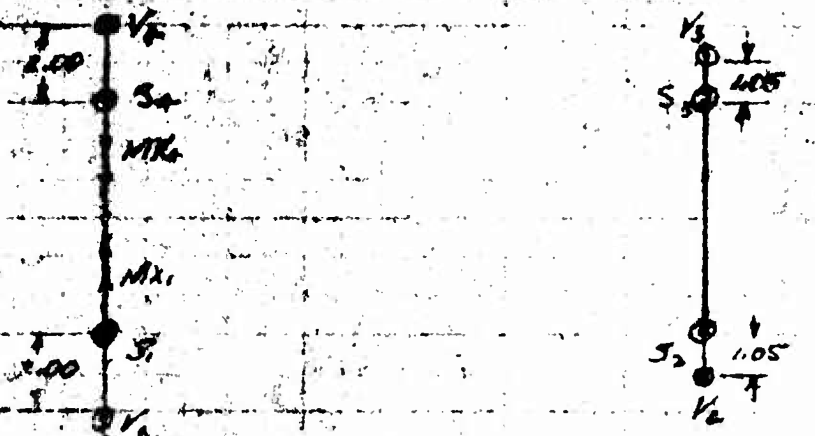
FOR FLAT PITCH $\gamma = 1° 38'$ (REF SEC 5.2.3)

$T_2 = T_1 = 79{,}000 \times \sin 1° 38' = 2250$ LBS.

RESULTANT TORQUE = $2250 \times 11.9 = 26{,}780$ IN LBS

* INCREASED TO 80,400 POUNDS EFFECT NEGLIBLE.

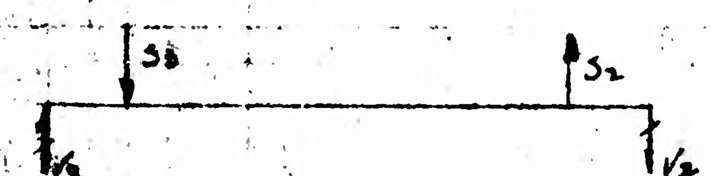
M_{X_1} & M_{X_4} ARE CARRIED IN THE FOLLOWING MANNER.



$$S_1 = S_2 = \frac{M_{X_1}}{(73-63)} = 11{,}850 \text{ LBS}$$

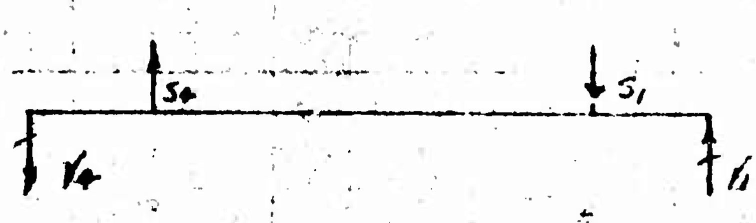
$$S_3 = S_4 = \frac{M_{X_4}}{(73-63)} = 9{,}880 \text{ LBS}$$

CONSIDER AN IMAGINARY BEAM LOADED THUS.



$$V_2 = \frac{-1.05 \times 9{,}880 + 13.85 \times 11{,}850}{15} = 10{,}330 \text{ LBS}$$

$$V_3 = 9{,}880 + 10{,}330 - 11{,}850 = 8360 \text{ LBS}$$



$$V_f = \frac{18.9 \times 11{,}850 - 2 \times 9{,}880}{16 \cdot 9} = 9280 \text{ LBS}$$

$$V_R = 9280 + 9880 - 11850 = 7310 \text{ LBS}$$

IN ADDITION THERE ARE SIDE LOADS FROM THE SPAR AT STA 73.00

C.F. FRONT SPAR STA 73 73,910 LBS
C.F. AFT SPAR STA 73 61,290 LBS.
} REF SECTION 4

FRONT KICK LOAD

73,910 TAN 6°22' = 8300 LBS

REAR KICK LOAD

61,290 TAN 4°38' = 4970 LBS.

SIDE LOAD DUE STRAP AND SPAR MISALIGNMENT

FRONT SPAR

79000 SIN 1°03' = 1450 LBS

AFT SPAR

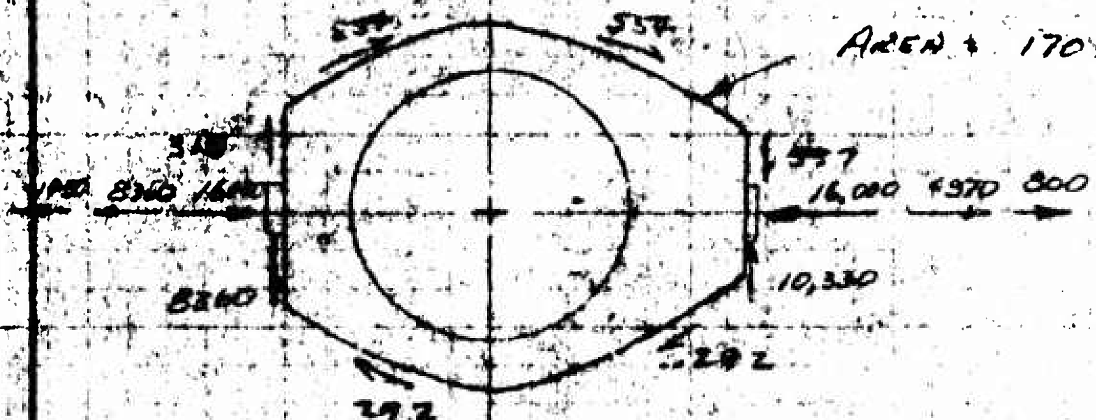
79000 SIN 35' = 804 LBS

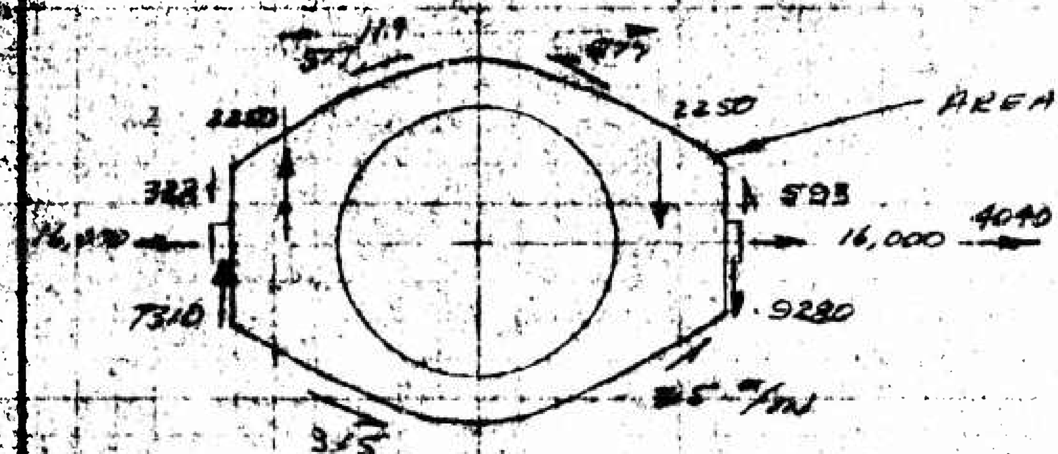
FITTING SIDE LOADS = 16,000 LBS (REF 5.2.7.31.)

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

BLADE STRUCTURE

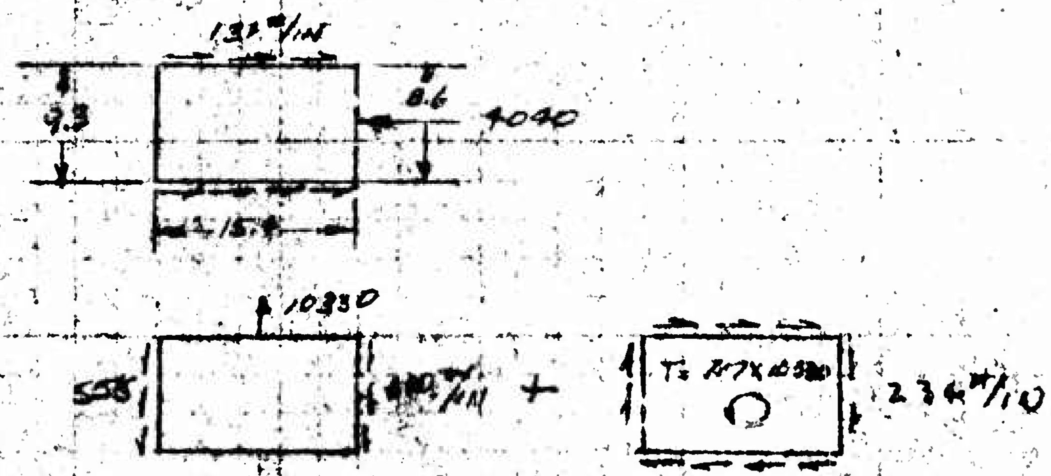
LOADS ACTING ON RIBS





CALCULATION OF SHEAR FLOWS *

STA. 73 BY SUPERPOSITION

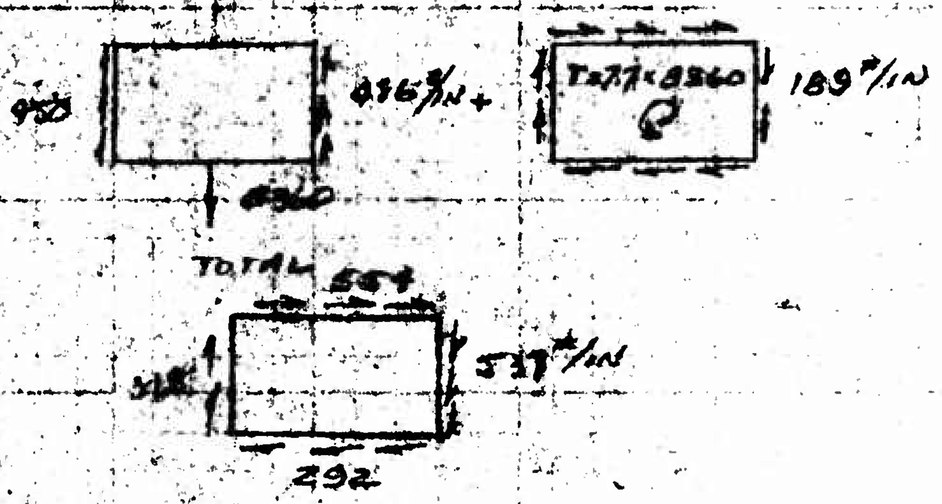


* THE DISSYMMETRY OF THE RIB IS NEGLECTED IN DETERMINING THE SHEAR FLOWS, ACTUAL FORCES ARE USED

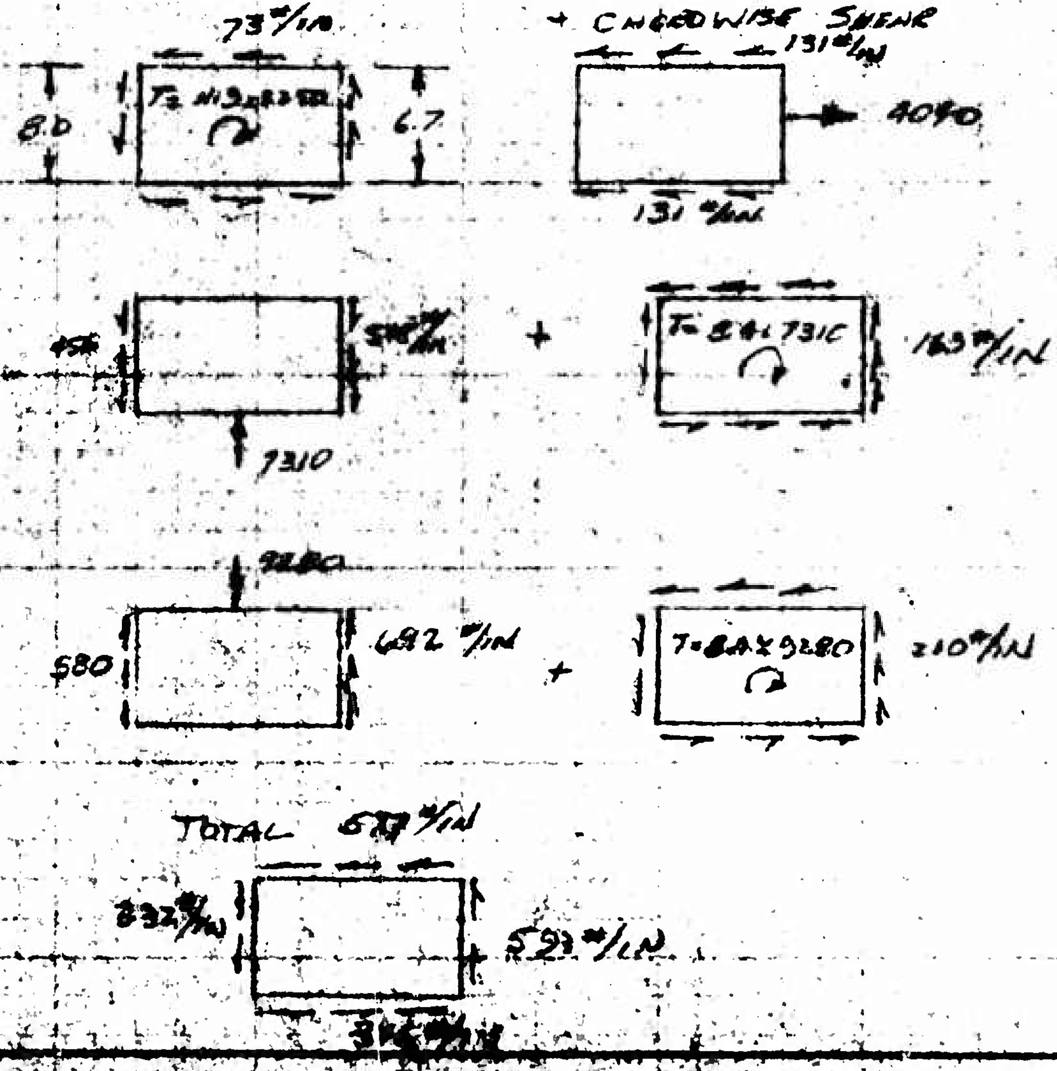
BLADE STRUCTURE

LOADS ACTING ON RIBS (CONT'D)

STA 73 CONT'D

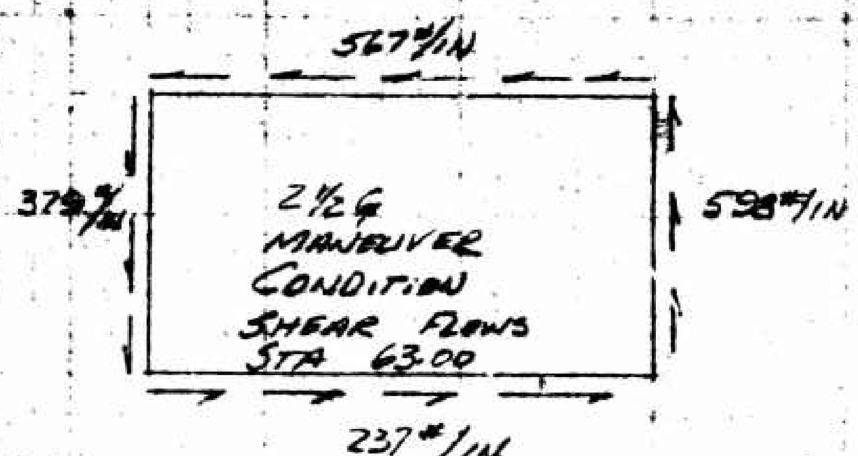


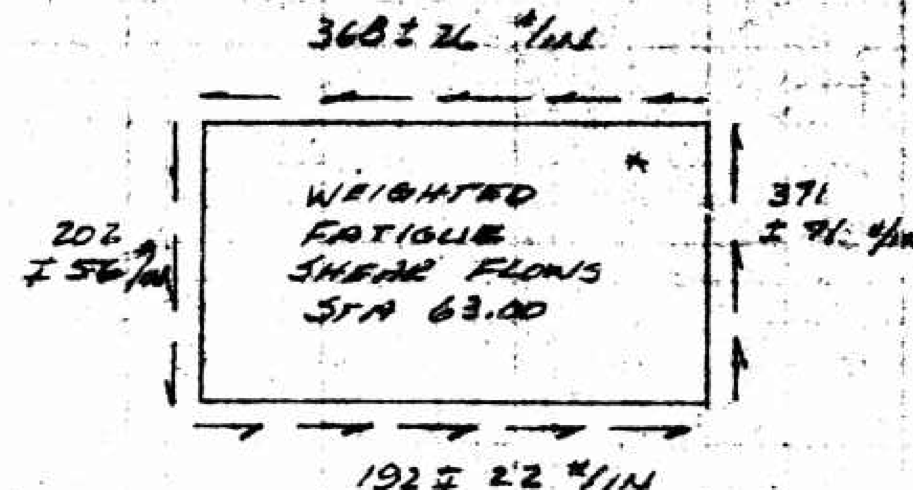
STA. 63.



SHEAR FLOWS ACTING ON RIBS

CONDITION	STRAP TENSION	M_{X1}	M_{X2}	V_1	V_2	STRAP TORQUE	KICK LOADS FRONT	KICK LOADS AFT	SLIDE LOADS FRONT	SLIDE LOADS AFT	FITTING SIDE LOAD
2½ G MANEUVER	63,500	95,250	79,380	8400	6810	50,100	5350	3190	880	409	12,700
WT. □ FATIGUE	51,200 ± 3810	76,800 ± 5730	69,000 ± 4775	6780 ± 510	5550 ± 620	±20,600	5350 ± 400	3190 ± 240	880 ± 66	409 ± 30	10,240 ± 768
FLAT PITCH	79,000	118,500	98,750	9280	7310	26,800	8360	4970	1450	802	16,000





□ THE CYCLIC PART OF THE STRAP LOAD ACTS SUCH THAT THERE IS LITTLE TORSION PRODUCED AND THE SHEAR FLOWS ARE ADDITIVE ON THE SIDES OF THE BOX.

* NEGLECTING STRAP TORSION.

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

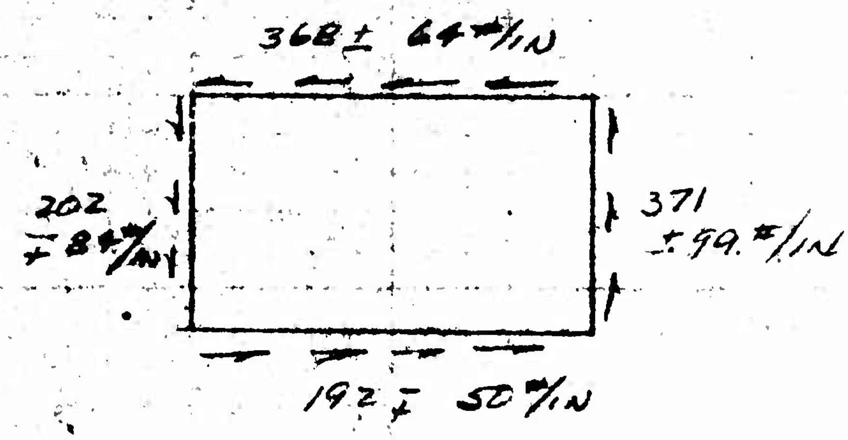
ANALYSIS: HOT CYCLE   MODEL: 285   REPORT NO. 285-13   PAGE 5.2.7.7

PREPARED BY: D.W. Nicholls 6-22-6   BLADE STRUCTURE 63-73

CHECKED BY:

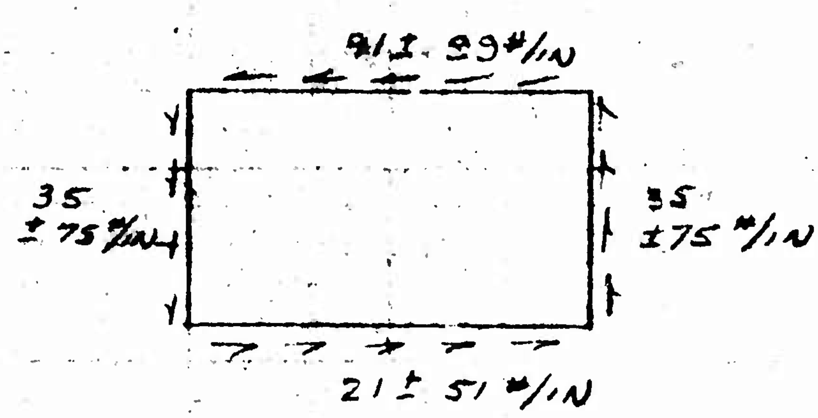
SHEAR FLOWS ON SKIN (63.00 TO 73.00)
WEIGHTED FATIGUE CONDITION

(INCLUDING BLADE TORSION)



SHEAR FLOWS ON SKIN INBOARD OF 63.00
WEIGHTED FATIGUE CONDITION

INCLUDING BLADE TORSION & STRAP TORQUE



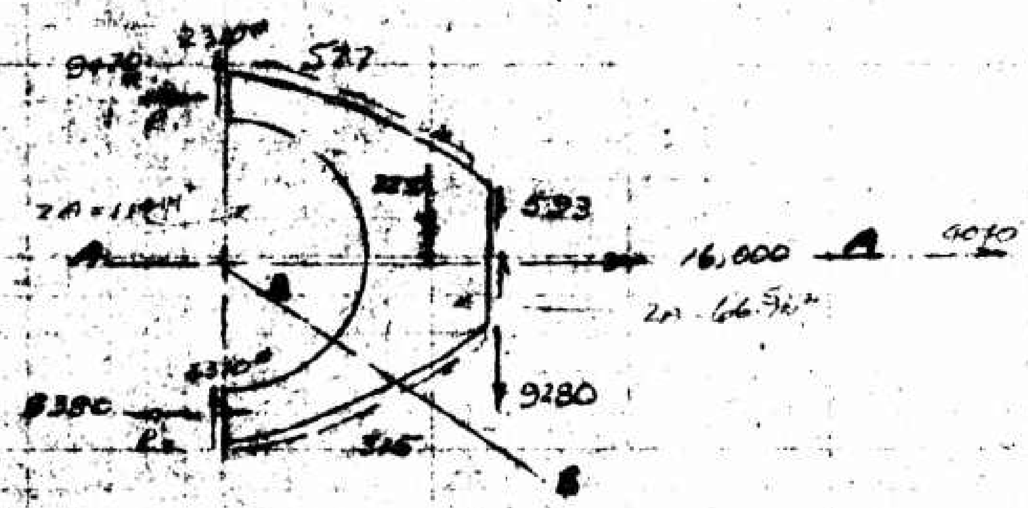
INBOARD OF 63.00 THE STRAP TORSION IS THE ONLY LOAD THAT IS TRANSFERED INTO THE SKIN FROM THE STRAP ATTACH FITTINGS.

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

MODEL 315 REPORT NO. 285-13 PAGE 5.2.7.8

BLADE STRUCTURE STA 63

STA 63.00 AFT SECTION 285-0128



NET VERTICAL REACTION

$-9280 + 2250 + 6.7(593) + 3.3(315) + 3.3(577) =$ [illegible]

ΣM_O LOWER SECTION = 0:

$11.5R_1 + 9280 \times 9.2 - 2250 \times 7.1 + 577(11.0) + 593(6.5)$

$-5.8(4010) - 16,000 \times 5.1 + 315(10.5) = 0$

$R_1 = \frac{108,900}{11.5} = 9470\#$

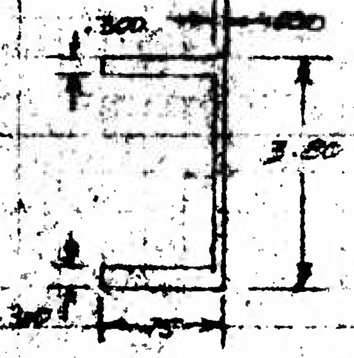
ΣM_O UPPER SECTION

$11.5R_2 - 16,000 \times 5.8 + 9280 \times 9.2 - 315(11.3) - 593(6.5)$

$-5.8(4010) + 2250(7.1) - 577(10.5) = 0$

$R_2 = \frac{96,340}{11.5} = 8380\#$ o.k.

MOMENT OF INERTIA AT SECTION A-A



$$I = \frac{.090 \times (3.80)^3}{12} + 2(.66 \times .3)(1.90)^2$$

$$= .412 + 1.429 = 1.841 \text{ IN}^4$$

$$A = .090 \times 3.80 + 2(.300 \times .66) = .738 \text{ IN}^2$$

$$M = 9470 \times 5.7 - 2310 \times 7.1 + 41.4 \times 577 + 5.6 \times 593$$

$$= 64,790 \text{ IN LBS}$$

$$V = 2310 + 3.3(572) + 3.3(593) = 6170 \text{ LBS}$$

$$f_b = \frac{64,790 \times 1.90}{1.84} = 66,900 \text{ psi} \quad \text{LIMIT}$$

$$f_T = \frac{6170}{.738} = 8360 \text{ psi} \quad \text{LIMIT}$$

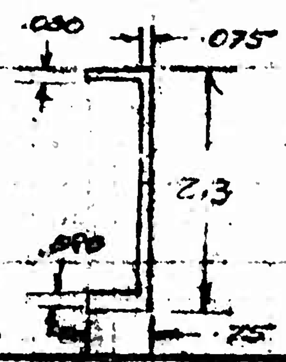
$$M.S. = \frac{150,000}{(75,260)(1.5)} - 1 = .32$$

NO CORRECTION FOR TEMP OF 250°F

SECTION B-B

SECTION B-B IS TAKEN AT 45°

MOMENT OF INERTIA.



$$I = \frac{.075(2.3)^3}{12} + 2(.080 \times .675)(1.15)^2$$

$$I = .082 + .142 = .224 \text{ IN}^4$$

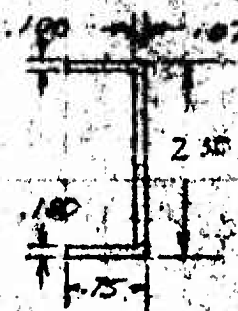
MOMENT AT SECTION B

[illegible] 18380 x 1.2 − 5.5 (315) = 18,720

$f_B = \dfrac{18,720 \times 1.15}{.224} = 96,100$ PSI LIMIT

$f_T = \dfrac{[illegible]}{2.30} = 15,300$ PSI LIMIT

INCREASE WEB THICKNESS TO .90 MIN. AND FLANGE THICKNESS TO .200 MIN. AND HEAT TREAT TO R.C. 30



$I = \dfrac{.075 (2.3)^3}{12} + 2(.100 \times .675)(1.15)^2 = .260 \text{ IN}^4$

$A = (2.30)(.075) + 2(.100 \times .675) = .307 \text{ IN}^2$

$Y_b = \dfrac{2(1.15 \times .075 \times .575 + .100 \times .675 \times 1.10)\, 1.15}{.260} = 1.10$

$F_{bu} = 150,000 \times 1.1 = 165,000$

$f_b = \dfrac{18,720 \times 1.15}{.260} = 82,800$ (LIM.)

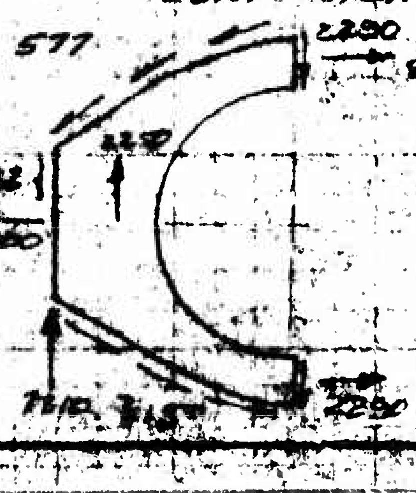
$R_b = \dfrac{124,200}{165,000} = .75$

$f_T = \dfrac{4290}{.307} = 14,000$ (LIM) $\quad R_T = \dfrac{21,000}{150,000} = .140$

$MS = \dfrac{1}{.75 + .14} - 1 = \underline{\underline{.12}}$

(NEGLECTING TEMP)

FRONT SECTION



NET VERTICAL REACTION

$V = -2250 - 7310 + 8(332) + 2.6(577) + 2.6(315)$

$= 4580$

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

REPORT NO. 285-13 PAGE 5.2.7.11

FLAT PITCH STA. 63

ΣM ABOUT LOWER END

$$11.5R_1 - 16000 \times 5.7 + 7.8(7310) - 99(577)$$

$$- 67(332) + 9(365) + 6(2250) = 0$$

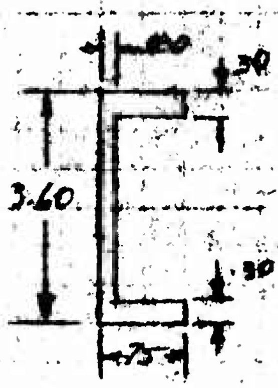
$$R_1 = \frac{102,870}{11.5} = 8950 \; \#$$

ΣM ABOUT UPPER END

$$11.5R_2 - 16,000 \times 5.7 - 7.8(7310) - 2250(6) + 99(365)$$

$$+ 67(332) + 9(579) = 0$$

$$R_2 = \frac{103,100}{11.5} = 8965 \; \#$$

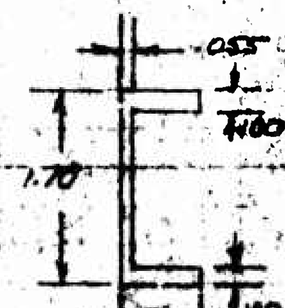


$$I = \frac{.09(3.6)^3}{12} + 2(.30 \times .660)(1.8)^2$$

$$= .349 + 1.283 = 1.63 \; IN^4$$

OK BY COMPARISON WITH THE OTHER SIDE.

CHECK ON MOMENT AT POINT OF INFLECTION.



$$I = \frac{.055(1.7)^3}{12} + 2(.100 \times .695)(.85)^2 = .123 \; IN^4$$

$$A = .055 \times 1.7 + 2(.100 \times .695) = .232 \; IN^2$$

FLAT PITCH RIB STA 63.00

STRESS AT POINT OF INFLECTION

$$f_T = \frac{9470}{.232} = 40{,}800 \text{ psi} \quad (\text{LIMIT})$$

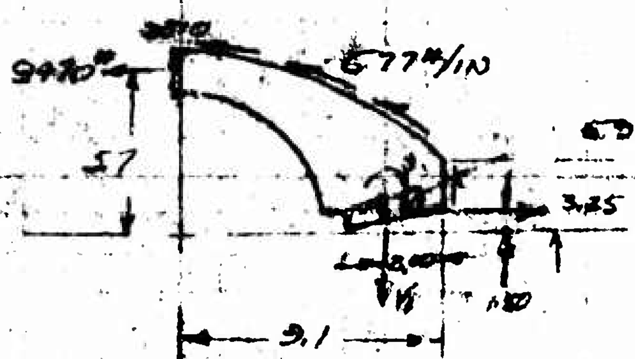
$$f_b = \frac{150{,}000}{1.5} - 40{,}800 = 59{,}200 \text{ psi LIMIT}$$

THIS CORRESPONDS TO A MOMENT OF

$$M = \frac{59{,}200 \times .123}{.85} = 8570 \text{ IN LBS.}$$

THEREFORE EVEN THOUGH THE ASSUMPTION OF AN INFLECTION POINT IS NOT CONSERVATIVE, THE SECTION IS STILL CAPABLE OF CARRYING A SIZEABLE MOMENT NEGLECTING TEMPERATURE

SECTION THROUGH STRAP HOLE



$$\Sigma F_V = 0. \quad -V_1 + 2310 + 577(2.3) + 593(1.50) = 0$$

$$V_1 = 4530\,\#$$

$$\Sigma F_H = 0$$

$$H_1 + 577 \times 9.1 + 9060 = 0$$

$$H_1 = 14{,}310\,\#$$

MOMENT AT STRAP HOLE

$M_1 - 9970 \times 4.2 - 2310 \times 7.1 - 577(28.5) - 573(3.8) = 0$

$M_1 = 74,860$ IN LBS

CONSIDER THE HOLE AS A SLOTTED BEAM

$f_T = \frac{MC}{I} + V_A \times \frac{\left[I_1 / (I_1 + I_2) \right]}{(I/c)_1}$ (REF ROARK PG 146)

$I = 2(.45 \times .75) \times (1.78)^2 = 2.13 \text{ IN}^4$

$C = 2.00$ IN $\qquad X_{MAX} = .50$

$V_A = 14,310$

$I_1 = .056 \text{ IN}^4$

$I_2 = .056 \text{ IN}^4$

$C_1 = .225$

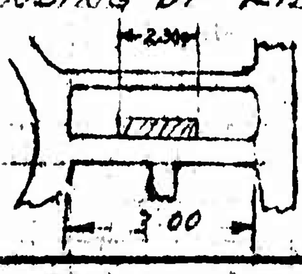
$f_T = \frac{74,860 \times 2.00}{2.13} + \frac{14,310 \times .5 \left[\left(\frac{.056}{.056 + .056} \right) \right]}{\frac{.056}{.225}}$

$f_T = 70,300 + 14370 + \frac{2265}{.75 \times .45} = 91,380$ PSI LIMIT

TENSILE LOAD

$M.S. = \frac{150,000}{91,380(1.5)} - 1 = \underline{\underline{.09}}$

BENDING OF RIB DUE TO LOAD FROM FITTING.



THE HIGHEST LOAD ON THE FITTING OCCURS IN THE 2½G MANEUVER CONDITION

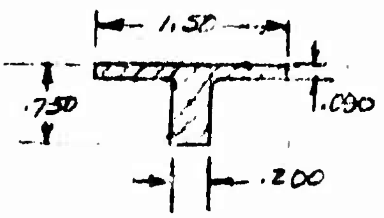
3704

LOAD DUE TO STRAP TWIST (3° 48' STRAP WRAP)

63,200 SIN 3° 48' = 4190 LBS LIMIT

ANY VERTICAL LOAD ON THE FITTING HAS 2 LOAD PATHS WHICH IT CAN FOLLOW, EITHER BEARING ON THE RIB OR THROUGH THE FASTENERS. IT IS ASSUMED THAT 1/3 OF THE LOAD IS CARRIED THROUGH THE FITTING LIP & 2/3 OF THE LOAD THROUGH THE FASTENERS.

TOTAL LOAD = 4190 + 11,850 = 16,040 LBS.

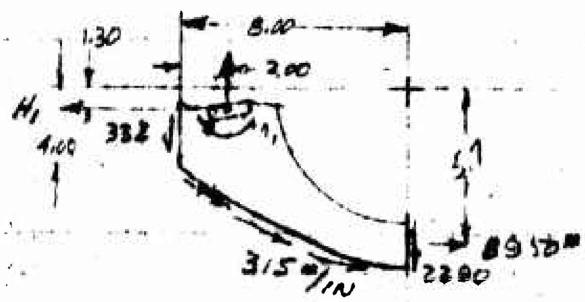


$A = .09(1.30) + .2(.75) = .267\ IN^2$

$f_c = \dfrac{16,040}{(3)(.267)} = 20,000$ PSI

M.S. HIGH

LOADS AT STRAP HOLE ON FORWARD SIDE OF HOLE.



$\Sigma F_V = 0$

$+2290 + 315(2.6) + 332(2.70) - V_1 = 0$

$V_1 = 4010\#$

$\Sigma F_H = 0$

$8950 + 8(315) - H_1 = 0$

$H_1 = 11,470$

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS Hot Cycle MODEL 285 REPORT NO. 285-13 PAGE 5.2.7.15

PREPARED BY D.W. Nicholls 4-5-60 CHECKED BY

FLAT PITCH STA 63.00

MOMENT AT FORWARD STRAP HOLE

$\Sigma M = 0$

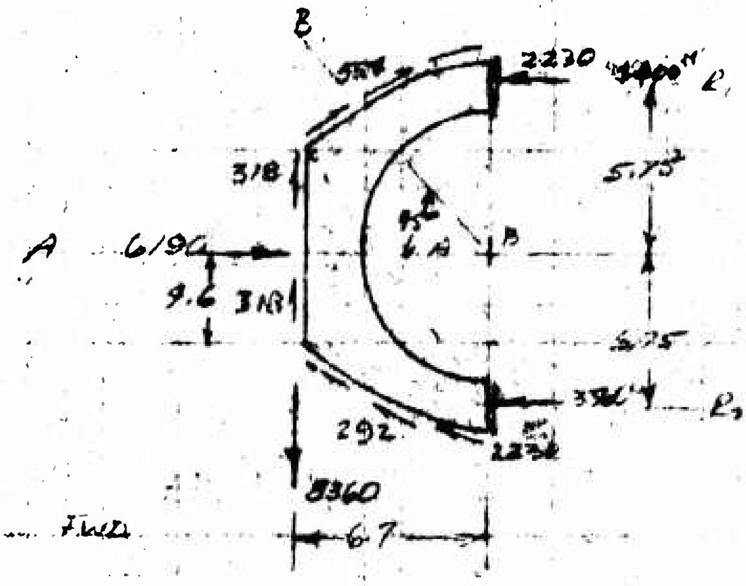
$M_1 + 8950(2.3) + 2290(6.0) - 315(29.0) - 332(4.9) = 0$

$M_1 = 35,470$ "#

THE LOADS ARE LESS THAN THOSE FOR THE OTHER SIDE OF THE RIB SO IT IS O.K. BY COMPARISON.

5706

ASSUME INFLECTION POINT ON CENTERLINE OF RIB 285-0129



$\Sigma F_V = 0$

$8360 - 318(9.2) - 292(1.15) - 554(1.15) - V_1 = 0$

$V_1 = 4460$

$\Sigma M_0 = 0$ LOWER END

$6190(5.75) - 8360(6.7) - 11.5 R_1 + 554(87.6) + 318(63) + 292(8.5) = 0$

$R_1 = \frac{50,620}{11.5} = 4400^{\#}$

$\Sigma M_0 = 0$ UPPER END

$6190(5.75) + 8360(6.7) - 11.5 R_2 - 292(86.3) - 318(65.3)$

$- 554(8.5) = 0$

$R_2 = \frac{40,935}{11.5} = 3560^{\#}$

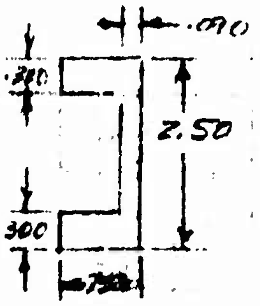
BENDING MOMENT AT SEC A-A

$M_A = 4400 \times 5.75 + 2230(5.5) - 554(35.2) - 318(5.5)$

$M_A = 16,320$ IN LBS

$V_A = 2230 + 318(4.6) + 554(2.0) = 4800$ #

$H_A = 4400 - 554(6.7) = 690$ #



$I = \frac{.090 \times (2.5)^3}{12} + 2(.3 \times .66)(1.10)^2 = .590\ IN^4$

$A = .090 \times 2.5 + 2(.3 \times .66) = .621\ IN^2$

$f_b = \frac{16,320 \times 1.25}{.590} = 34,570$ psi LIMIT

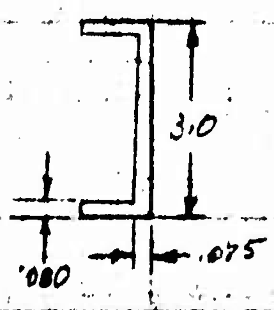
$f_T = \frac{4800}{.621} = 7730$ psi LIMIT

$M.S. = \frac{150,000}{(34,570 + 7730)1.5} - 1 = \underline{1.36}$

NO TEMP CORRECTION

BENDING MOMENT AT SECT B-B

$M_B = 4400(1.6) + 2230(4.3) = 16,630$ IN LBS (NEGLECTING SHEAR FLOW)



$I = \frac{.075(3.0)^3}{12} + 2(.080 \times .675)(1.46)^2 = .398\ IN^4$

$A = .075(3.0) + 2(.080 \times .675) = .333\ IN^2$

$f_{LA} = \frac{16,630 \times 1.5}{.398} = 62,630$ psi LIMIT

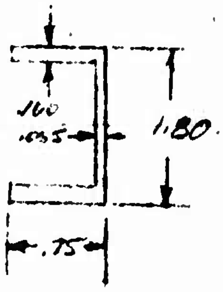
TENSILE FORCE ACTING

$4400 \times .707 - 2230 \times .707 = 1530$ LBS

$f_T = \frac{1530}{.338} = 4590$ psi LIMIT

$MS = \frac{150,000}{(67,220)1.5} - 1 = \underline{\underline{.49}}$

BENDING MOMENT AT INFLECTION POINT



$I = \frac{.055(1.80)^3}{12} + 2(.100 \times .695)(.90)^2 = .139 \text{ in}^4$

$A = (.055)(1.80) + 2(.100 \times .695) = .238 \text{ in}^2$

$f_t = \frac{4400}{.238} = 18500$

$\frac{150,000}{1.5} - 18,500 = 81,500$

THIS CORRESPONDS TO A BENDING MOMENT OF

$M = \frac{81500 \times .139}{.90} = 12,590$ IN LBS.

SINCE THE SECTION IS CAPABLE OF CARRYING A LARGE MOMENT THE EXACT LOCATION OF THE INFLECTION POINT IS NOT TOO CRITICAL.

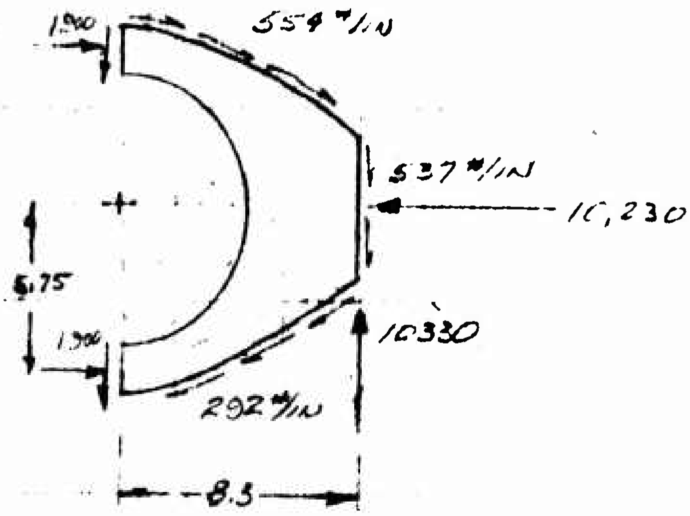
HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS Hor Shear　　MODEL 285　　REPORT NO. 285-13　　PAGE 5.2.7.19

PREPARED BY T.W. Nichols 4-8-60　　FLAT PITCH　　STA 73.10

CHECKED BY

AFT SECTION.



$\Sigma F_V = 0$

$$10330 - 537 \times 7.6 - 554(2.9) - 292(2.9) - V_1 = 0$$

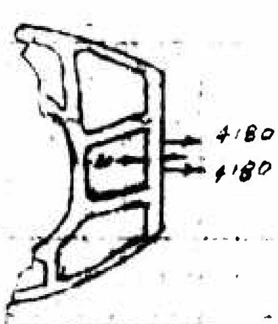
$V_1 = 3790$ LBS　(ERROR DUE TO ASSUMPTION OF A SYMMETRICAL SECTION)

$\Sigma M_o = 0$　LOWER SECTION

$$10{,}230 \times 5.75 - 292(9.7) - 537(70.7) - 554(10.5) + 10330(8.6) - R_1 11.5 = 0$$

$$R_1 = \frac{48{,}690}{11.5} = 4240^{\#}$$

SPAR ATTACH SECTION



SINCE THE SPAR BOLTS INTO A PLATE INSIDE THE FLANGE OF THE RIB THE BOLT LOAD WILL BE ASSUMED TO BE UNIFORMLY DISTRIBUTED.

8704

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE — MODEL: 285 — REPORT NO. 285-13 — PAGE: 5.2.7.26

PREPARED BY: D. W. NICHOLLS 4-1960 — FLAT PITCH — STA 73.00

CHECKED BY:

$$MAX.\ M = \frac{1}{12} W\ell$$

$$M = \frac{8360 \times 2.7}{12} = 1880 \text{ IN LBS}$$

$$I = \frac{.75(.3)^3}{12} = 1.68 \times 10^{-3}$$

$$f_b = \frac{1880 \times .15}{1.68 \times 10^{-3}} = 167{,}900 \text{ psi}$$

THIS IS ASSUMING THAT THE FLANGE ONLY IS ACTIVE IN RESISTING THE LOAD. THE WEB WILL CERTAINLY MAKE A SIGNIFICANT CONTRIBUTION.

THE BENDING MODULUS OF RUPTURE YIELD STRENGTH IS 163,000 psi FOR K=1.5 (RECTANGULAR SECTION)

CHANGE SECTION THICKNESS TO .400 MIN.

$$I = \frac{.75(.40)^3}{12} = 4 \times 10^{-3} \text{ IN}^4$$

$$f_b = \frac{1880 \times .20}{4 \times 10^{-3}} = 94{,}000 \text{ psi LIMIT}$$

$$F_{TBM} = 220{,}000 \text{ psi}$$

IN ADDITION THE BENDING STRESS DUE TO RIB LOADS MUST BE ADDED. 34,570 psi (LIMIT)

$$R_b = \frac{141{,}000}{220{,}000} = .64$$

$$R_T = \frac{51{,}850}{150{,}000} = .35$$

$$M.S = \frac{1}{.64 + .35} - 1 = \underline{\underline{.01}}$$

9704

PRE LOAD IN SPAR ATTACH BOLTS.

USE THE WEIGHTED FATIGUE CONDITION

THE STEADY KICK LOAD IS 5350 # (REF 5.2.7.6)

THE CYCLIC AXIAL LOAD IN THE SPAR = $\pm\frac{32,100}{15}$

$= \pm 5500$ #

CYCLIC KICK LOAD = $\pm 5500 \sin 6°22' = \pm 610$ #

IN ADDITION THERE IS A MOMENT RESULTING FROM THE CHORDWISE BENDING MOMENT.

MOMENT AT STA 73 = 1000 ± 14000 IN LBS

MOMENT ON BOLTS IS

$(9000 \pm 14000) \sin 6°22' = 1000 \pm 1550$ IN LBS

LOAD PER BOLT IS

$\frac{1000 \pm 1550}{1.2} = 830 \pm 1290$ LBS.

TOTAL LOAD PER BOLT

$\frac{5350}{2} \pm \frac{610}{2} + 830 \pm 1290$ LBS = 5120 LBS

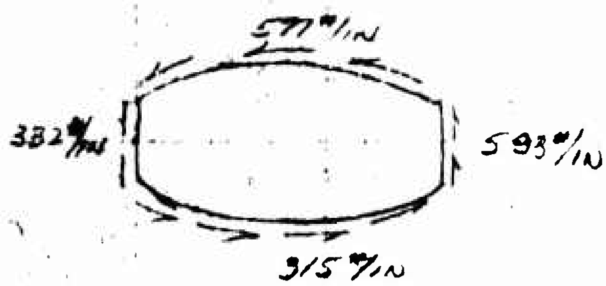
$f_T = \frac{5120}{.07669} = 67,000$ PSI

TORQUE = $.00269 \times 67,000 = 180$ IN LBS.

USE 170 TO 200 IN LBS

THE SHEAR FLOWS ARE HIGHEST AT STA 63.00

TOP & BOTTOM PANELS



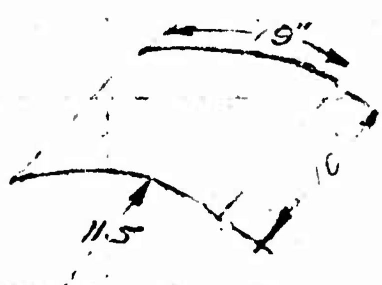
IN ADDITION TO THE LOADS ACTING ON THE RIB THERE IS A UNIFORM SHEAR DUE BLADE TORSION FOR 2½ G MANEUVER CONDITION $T = 20{,}170 \pm 32{,}300''$#

THIS GIVES A UNIFORM SHEAR FLOW OF

$$q = \frac{52{,}470}{340} = 154\#/IN.$$

MAX SHEAR IN SKIN 731#/IN LIMIT.

CONSIDER AS THE PANEL THE WHOLE SKIN NEGLECTING THE INNER WEB-17



BELL MANUAL 130.03.2-1

$$Z = \frac{10^2}{11.5 \times .071}\sqrt{1-.33^2} = 115$$

$$\frac{a}{b} = \frac{19}{10} = 1.90$$

$$K_s = 55$$

$$\frac{b}{t\sqrt{K_s}} = \frac{10}{.071\sqrt{55}} = \frac{10}{.526} = 19.0$$

SKINS 63.00 TO 73.00

$F_{su} = 22{,}000$ PSI

$f_s = \frac{731}{.071} = 10{,}300$ PSI LIMIT

$$M.S. = \frac{22{,}000}{(10{,}300)(1.5)} - 1 = \underline{\underline{.42}}$$

THE ABOVE VALUE IS NOT EXACT SINCE THE SHEAR FLOW FOR FLAT PITCH OVERREV WAS ADDED TO THE SHEAR FLOW FROM BLADE TORSION IN THE 2½ G MANEUVER CONDITION. ALSO THE TEMPERATURE OF THE SKIN (175°F) WAS NOT TAKEN INTO ACCOUNT SINCE FOR TEMPERATURES LESS THAN 200°F THERE IS ONLY A SMALL CHANGE IN MECHANICAL PROPERTIES.

USING 3/16" STEEL FASTENERS ON 1¼ MAX CENTERS THE LOAD PER BOLT IS 1080# ULTIMATE

FOR STEEL FASTENERS THE SKIN BECOMES CRITICAL IN BEARING

$P_{BR} = 1356$

$$M.S. = \frac{1356}{1080} - 1 = \underline{.26}$$

FOR THE BOTTOM SKIN DD6 RIVETS CAN BE USED ON 1 INCH CENTERS

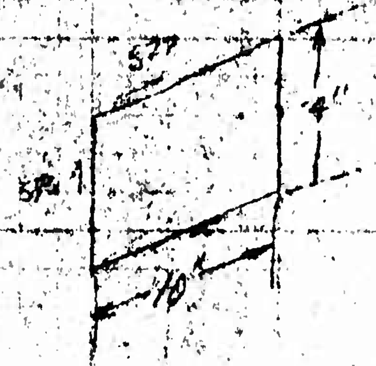
SHEAR FLOW 315#/IN (LIMIT)

P_S DD6 IN .071 SKIN = 1180 LBS

$$M.S. \frac{1180}{(315)1.5} - 1 = \underline{\underline{1.50}}$$

SKINS 63.00 TO 73.00

SIDE SHEAR PANEL



$\frac{b}{a} = \frac{4}{10} = .4$

$K_s = 5.4$

$\frac{F_{scr}}{\eta} = 5.4 \times 10^7 \times \left(\frac{.071}{4}\right)^2$

$F_{scr} = 17,000$ PSI $\quad (\eta = 1)$

SHEAR FLOW = 593 + 154 = 748 #/IN (LIM)

$f_s = \frac{748 \times 1.5}{.071} = 15,800$ PSI

$M.S. = \frac{17,000}{15,800} - 1 = .08$

THE MARGIN IS BASED ON CRIPPLING ALLOWABLE AND IS CONSERVATIVE BECAUSE THE CLAMPING EFFECT OF THE SPAR WAS NEGLECTED AND THE PANEL HEIGHT WAS CONSERVATIVELY ESTIMATED AT 4".

THE BOTTOM ROW OF RIVETS SHOULD CARRY AT LEAST 577 #/IN. LIMIT. RIVET SHEAR IS CRITICAL ON 1" SPACING.

$M.S. = \frac{1180}{(577)1.5} - 1 = .37$

COVER PLATE.

THE COVER PLATE WILL BE SUBJECT TO THE SAME SHEAR FLOWS AS THE TOP SKIN OR 731 #/IN. LIMIT.

FOR NAS 1403 SCREWS THE HOLES ARE CRITICAL IN BEARING. FOR .071 SKIN P_{br} = 1356 LBS.

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS Hat Cycle MODEL 285 REPORT NO. 285-13 PAGE 5.2.7.24

PREPARED BY D.W. Nicholls

CHECKED BY

SKINS 63.00 TO 73.00

COVER PLATE CONTINUED

SCREW SPACING WILL BE ABOUT 1"

$$M.S. = \frac{1356}{(.731)(45)} - 1 = \underline{\underline{.24}}$$

9704

STRAP ATTACH FITTING OUTBOARD

DWGS. 285-0163 & 285-0164

INTRODUCTION

THE PRIMARY PURPOSE OF THE STRAP ATTACH FITTING IS TO TIE THE WING STRAPS TO THE SPARS. THE FITTING IS ATTACHED TO THE STRAP WITH (3) 5/8" STEEL BOLTS IN DOUBLE SHEAR AND TO THE SPAR WITH (7) 1/2" STEEL BOLTS. THE FITTING ALSO TIES TO HEAVY RIBS AT STA. 63 & 73. THE FITTING IS MACHINED FROM 4340 STEEL AND IS HEAT TREATED TO 160-180,000 PSI. THE ELEVATED TEMPERATURE OF THE FITTING IS APPROXIMATELY 300°F.

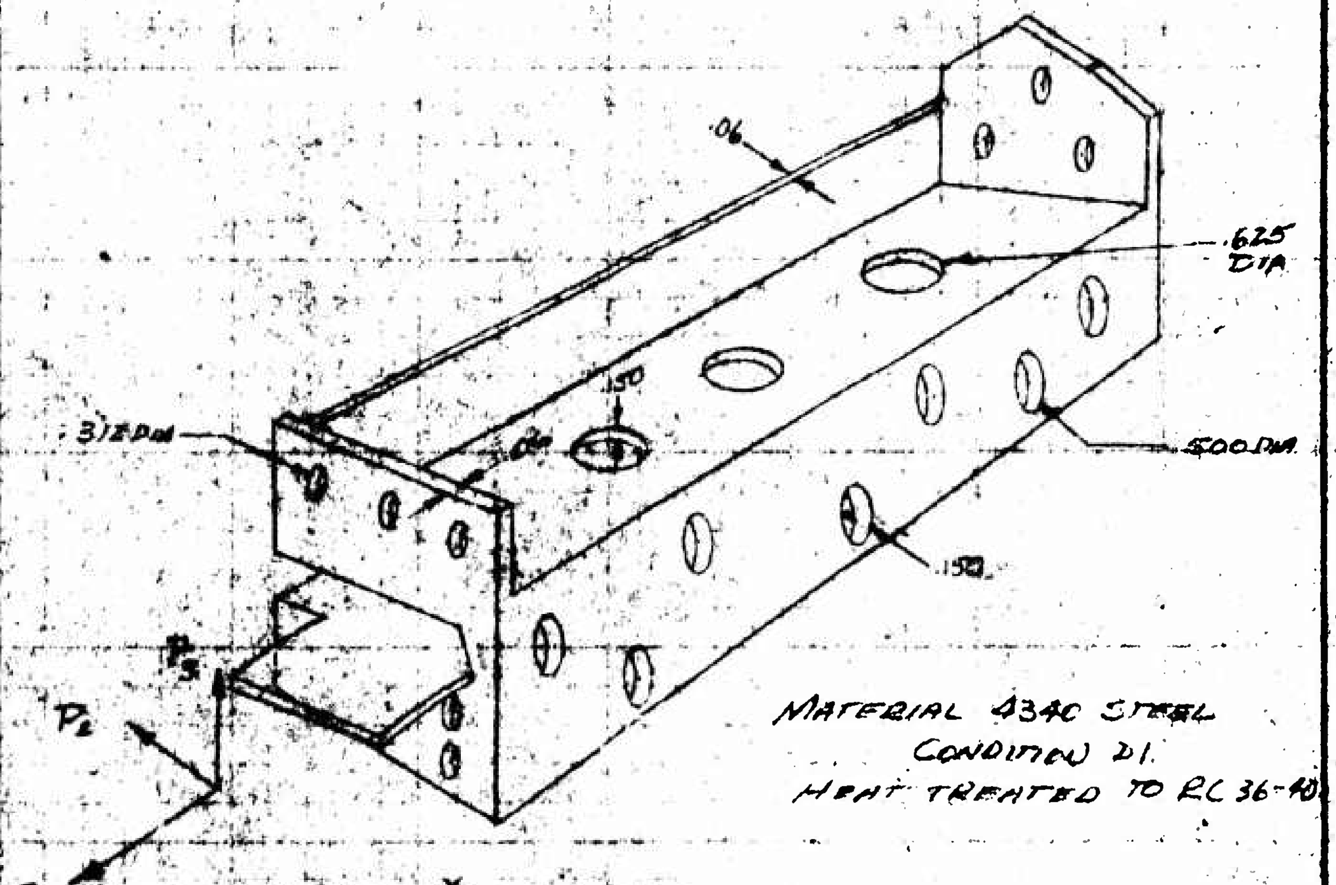
THE ASSUMED LOAD DISTRIBUTION IS THAT THE STRAP AXIAL LOAD IS TRANSFERRED TO THE SPARS WITH THE UNBALANCED MOMENTS BEING RESISTED AS COUPLE LOADS BY THE RIBS AT STA. 63 AND 73. THE OUTBOARD END (STA 93) OF TH FITTING IS LOADED BY A CENTRIFUGAL FORCE LOAD FROM THE OUTBOARD DUCT.

THE FOLLOWING ARE UNCORRECTED CHANGES IN THE ANALYSIS

1) THE BLADE WAS BALANCED ABOUT THE FEATHERING AXIS PRODUCING EQUAL C.F. LOADS IN THE STRAPS AND THE BLADE IS NOW BALANCED ABOUT THE 25% CHORD. THIS DISTRIBUTES THE C.F. LOAD, 52% TO FWD. STRAP AND 48% TO AFT STRAP.

2) THERE HAVE BEEN SOME SMALL CHANGES IN STRAP GEOMETRY.

STRAP ATTACH FITTING OUTBOARD 285-0164



MATERIAL 4340 STEEL
CONDITION D1
HEAT TREATED TO RC 36-40

LOAD DIAGRAM *

CONDITION	P_1^{Δ}	P_2	P_3
2½ G MANEUVER	63 500	7100	3600
WEIGHTED FATIGUE	54 200 ± 3500	6200 ± 460	7800 ± 1520
FLAT PITCH OVER REV	79,600	8930	1540

(REF SECTION 4.3)

Δ INCLUDES DUCT PRESSURE LOAD.

* THE LOADS SHOWN INCLUDE 5% INCREASE TO ACCOUNT FOR CHANGE IN SPAR WEIGHT & BALANCE, DUCT PRESSURE

STRAP ATTACH BOLT HOLES

TOTAL TENSION ON STRAP (LIMIT LOADS)

$2\tfrac{1}{2}$ G MANEUVER $= \sqrt{(63,500)^2 + (7100)^2 + (13600)^2} = 65,200$ LBS

WEIGHTED FATIGUE $= \sqrt{(51,200 \pm 3820)^2 + (5700)^2 + (7800 \pm 1520)^2} = 52,050 \pm 3880$

FLAT PITCH OVERREV $= \sqrt{(79,600)^2 + (8980)^2} = 80,100$ LBS

THE THREE BOLTS WHICH FASTEN THE STRAP TO THE FITTING CARRY TOTAL TENSION AND IT IS ARBITRARILY ASSUMED THAT THE FIRST & LAST BOLTS CARRY 40% OF THE LOAD.

BOLT BEARING

BEARING AREA $.625 \times 2(.150) = .187$ IN^2

$f_{br} = \dfrac{80,100 \times .4}{.187} = 171,300$ PSI (LIMIT)

F_{br} ROOM TEMP 297,000

AT 400° $297,000 \times .89 = 264,300$ PSI

$M.S. = \dfrac{264,300}{1.5(171,300)} - 1 = \underline{\underline{.03}}$

BOLT SHEAR

SHEAR AREA $1.5 \times 4(.150) = .90$

$f_s = \dfrac{32,400}{.90} = 36,000$ PSI (LIMIT)

M.S. LARGE

$f_{s\,fat} = \dfrac{20,820}{.90} \pm \dfrac{1550}{.90} = 23,130 \pm 1720$ PSI

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

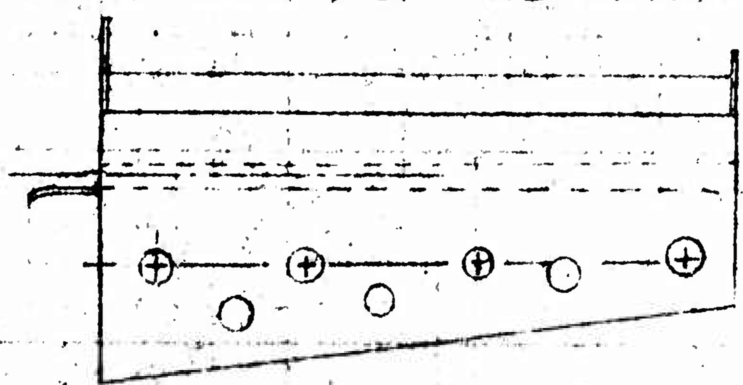
ANALYSIS HOT CYCLE MODEL 285 REPORT NO. 285-13 PAGE 5.7.7.25

PREPARED BY DWL NICHOLLS 2-3-60 STRAP ATTACH FITTING, OUTBRD

CHECKED BY

SPAR ATTACH BOLT HOLES

ASSUME THAT THE LOAD IS DIVIDED EQUALLY AMONG THE SEVEN BOLTS THAT ATTACH THE FITTING TO THE SPAR. IN ADDITION THERE IS A MOMENT CAUSED BY THE ECCENTRICITY OF THE FITTING (1.3 INCHES)



BOLT CHECK

MOMENT OVER REV = 80,100 × 1.3 = 104,130 IN LBS.

MOMENT FATIGUE = (52,050 ± 3880) 1.3 = 67,670 ± 5040 IN LBS

OVER REV

PRIMARY SHEAR

$$\frac{80,100}{7} = 11,440 \text{ LBS (LIMIT)}$$

RESULTANT SHEAR 14,100 LBS. (LIMIT)

P_S NAS 148 SINGLE SHEAR 18,650 LBS.

$$M.S. = \frac{18,650}{11,440 \times 1.5} - 1 = \underline{\underline{.08}}^{*}$$

WEIGHTED FATIGUE

$$\frac{(67,670 \pm 5040) \times 4.2}{53.62} = 5310 \pm 400 \text{ LBS} \quad \text{SECONDARY SHEAR}$$

$$\frac{52,050 \pm 3880}{7} = 7430 \pm 540 \text{ LBS} \quad \text{PRIMARY SHEAR}$$

* NEGLECTING ANY MOMENT CARRIED BY THE BOLTS

SPAR ATTACH BOLT HOLES (CONT'D)

WEIGHTED FATIGUE (CONT'D)

RESULTANT SHEAR 9230 ± 770 LBS.

$$f_s = \frac{9230 \pm 770}{.1503} = 61,400 \pm 5,00 \text{ PSI}$$

BOLT BEARING

BEARING AREA = .5 × .150 = .075 IN^2

$$f_{br} = \frac{11,440}{.075} = 152,500 \text{ PSI (LIMIT)}$$

$$M.S. = \frac{264,300}{(152,500)(1.5)} - 1 = \underline{.15} \ *$$

BOLT SHEAR OUT

TOTAL SHEAR AREA = 2 × (.10 × 6) .150 = 1.98 IN^2

$$f_s = \frac{80,100}{1.98} = 40,500 \text{ PSI}$$

F_s = 99,000 PSI AT ROOM TEMP

F_s = 99,000 (.89) = 88,100 PSI AT 400°

NOTE: FOR ANY PARTICULAR BOLT TO SHEAR OUT IT IS NECESSARY FOR ALL BOLTS TO FAIL.

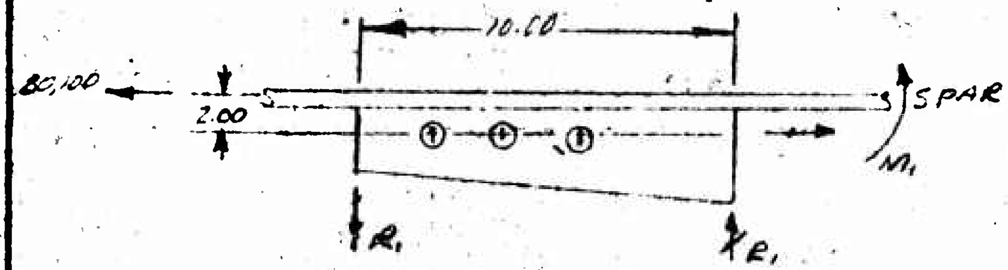
$$M.S. = \frac{88100}{40500 \times 1.5} - 1 = .45$$

$$f_s = \frac{9230 \pm 770}{.180} = 51,300 \pm 4280$$

* NEGLECTING ANY MOMENT CARRIED BY SPAR ATTACH BOLTS

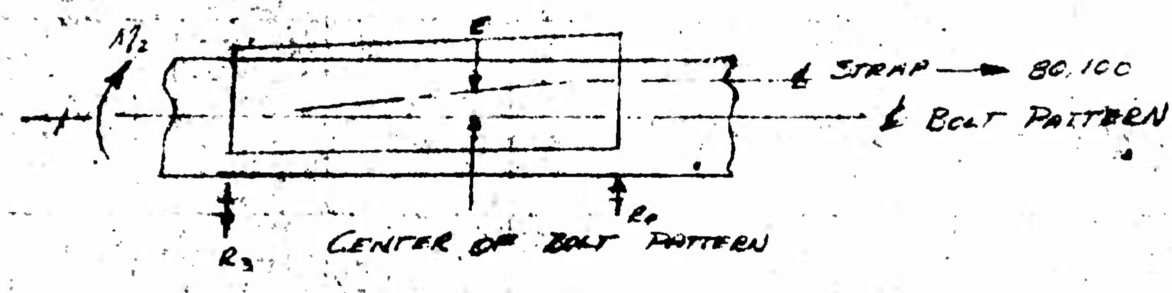
RIB ATTACH BOLT HOLES.

IN ADDITION TO THE SIDE LOAD ON THE FITTINGS THERE ARE MOMENTS DUE TO ECCENTRICITY WHICH ALSO MUST BE TAKEN OUT AS SHEAR ON THE JO-BOLTS.



$M_1 = 80100 \times 2 = 160,200$ IN LBS

$R_1 = R_2 = \frac{160,200}{10} = 16000$ LBS.



FOR THE FRONT STRAP e = 1.45
FOR THE AFT STRAP e = 1.65

$M_2 = 80,100 \times e$

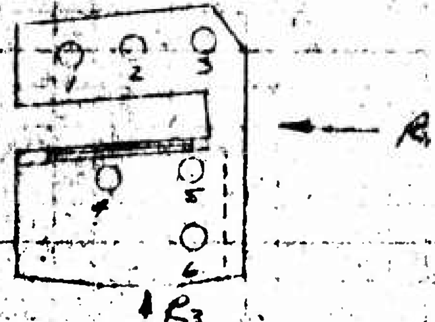
$M_{2F} = 80,100 \times 1.45 = 116,100$ IN LBS

$M_{2R} = 80,100 \times 1.65 = 132,160$ IN LBS

$R_{3F} = R_{4F} = \frac{116,100}{10} = 11,600$ LBS

$R_{3R} = R_{4F} = \frac{132,160}{10} = 13,220$ LBS

RIB ATTACH BOLT HOLES (CONT'D)



TYPICAL BOLT PATTERN

AS CAN BE SEEN FROM THE TYPICAL BOLT PATTERN A LOAD IN THE R_1 DIRECTION IS CARRIED BY ALL SIX BOLTS EQUALLY.

$$\text{THE } R_1 \text{ LOAD} = \frac{16{,}000}{6} = 2670 \text{ LBS.}$$

BUT THE LOAD IN THE R_3 DIRECTION MUST BE CARRIED PRINCIPALLY BY BOLTS 4, 5, & 6.

$$R_3 \text{ / BOLT} = \frac{13{,}220}{3} = 4{,}410 \text{ LBS}$$

RESULTANT SHEAR

$$\frac{8980}{12} = 750 \text{ LBS DUE TO SIDE LOAD, } P_z$$

$$S = \sqrt{(2670+750)^2 + (4410)^2} = 5580 \text{ LBS LIMIT}$$

IF A $\frac{3}{8}$" JO- BOLT IS USED S_{ALLOW} 21,000 DOUBLE SHEAR

$$M.S. = \frac{10{,}500}{5580 \times 1.5} - 1 = \underline{\underline{.25}}$$

RIB ATTACH BOLT HOLES (CONT'D)

BOLT BEARING:

BEARING AREA = .375 x .09 = .03375

$$f_{BR} = \frac{5580}{.0337} = 165,600 \text{ psi}$$

$$F_{BR} = 264,300 \qquad M.S. = \frac{264,300}{(165600)(1.5)} - 1 = \underline{\underline{.06}}$$

BOLT SHEAR OUT

SHEAR AREA = 2 x 1 x .06 = .12

$$f_s = \frac{5580}{.12} = 46,500 \text{ psi (LIMIT)}$$

$$F_s = 88,100 \qquad M.S. = \frac{88,100}{46,500(1.5)} - 1 = \underline{\underline{.26}}$$

$$f_{s\,FAT} = \frac{2180 \pm 165}{.12} = 18,160 \pm 1375 \text{ psi}$$

FITTING WEB

MINIMUM WEB THICKNESS = .25 IN.

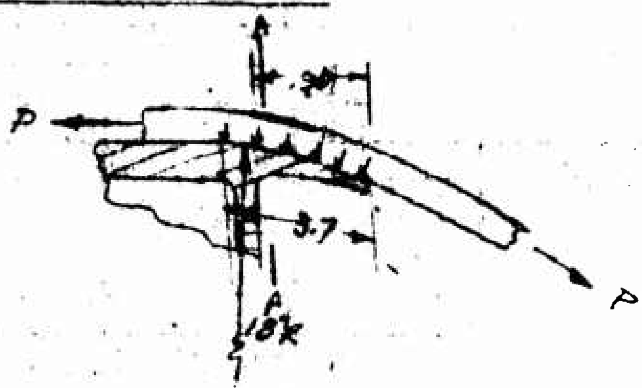
SHEAR AREA = 2.50

$$f_s = \frac{80,100}{2.50} = 32000 \text{ psi (LIMIT)}$$

$$F_s = 88,100 \qquad M.S. = \frac{88,100}{(32000)(1.5)} - 1 = \underline{\underline{.83}}$$

STRAP ATTACH FITTING, OUTBOARD

SHOE EXTENSION



FROM PAGE 5.2.3.11 IT CAN BE SEEN THAT THE MOST CRITICAL CONDITION FOR THE SHOE EXTENSION IS 4.95 ± 2.85° OR A TOTAL MAXIMUM CONTACT ANGLE OF 7.80° IN 2½ G MANEUVER.

TANGENT POINT 2.6 INCHES FROM LIP.

$18 \sin 7.8° = 2.45$ INCHES

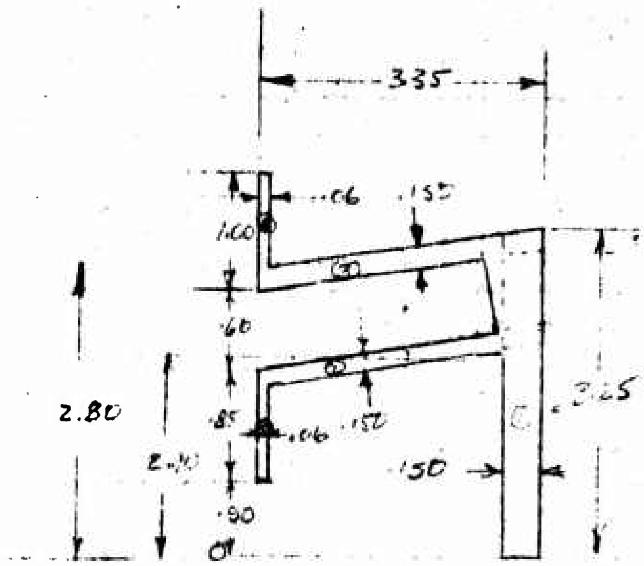
THE SHOE EXTENSION WILL NOT EXPERIENCE ANY LOAD FOR THE MOST SEVERE CONDITION OF STRAP WRAP.

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS HOT CYCLE — MODEL 285 — REPORT NO. 285-13 PAGE 5.2.7.35

PREPARED BY D.W. NICHOLLS 4-21-60 — FITTING ATTACH. C164

CHECKED BY



SECTION A-A 285-0164

ITEM	A	Y	AY	I_c	D	D^2	AD^2
1	.487	1.62	.789	.429	.56	.313	.152
2	.502	2.10	1.054	.020	.08	.0064	.003
3	.502	2.80	1.406	.020	.62	.384	.193
4	.060	2.85	.171	.005	.67	.449	.027
5	.051	1.32	.067	.003	.86	.740	.038
	1.602		3.487	.477			.413

$\bar{Y} = \frac{3.487}{1.602} = 2.18$ IN.

$I_{NA} = .477 + .413 = .890$ IN^4

MAX C = 2.18 IN.

9704

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS Hot Cycle MODEL 285 REPORT NO. 285-13 PAGE 5.2.7.36
PREPARED BY D.W. Nichols 4-22-60
CHECKED BY

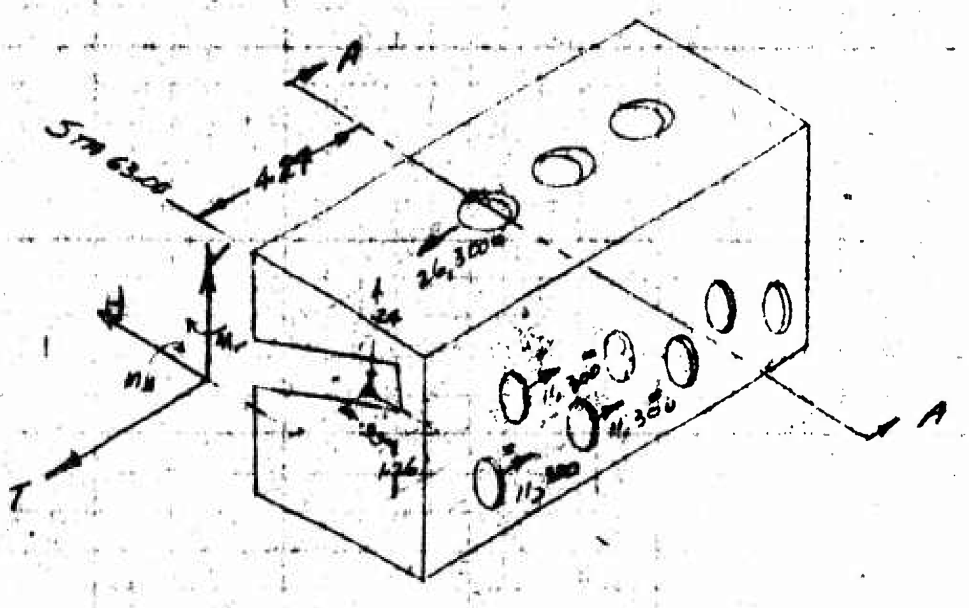
ATTACH FITTING 285-0164

ITEM	A	Y	AY	I_o	D	D^2	AD^2
①	.187	.075	.037	0	.915	.837	.407
②	.502	1.175	.590	.450	.185	.034	.017
③	.502	1.175	.590	.450	.185	.034	.017
(4+5)	.111	3.320	.368	0	2.330	5.43	.602
	1.602		1.585	.900			1.043

$$\bar{Y} = \frac{1.585}{1.602} = .990$$

$I_{YY} = 1.983 \text{ IN}^4$

MAX C = 2.360 IN.



T = 79,000 #
H = 16,000 #
V = 11,800 #

MOMENTS AT SECT A-A

$$M_H + 4.27(11,800) - 26,300 \times .24 - 3(11,300) \times 1.26 = 0$$

$$M_H = -1400 \text{ IN LBS (LIMIT)}$$

$$M_V + 4.27(16,000) - 3(11,300) \times .99 - 26,300 \times .81 = 0$$

$$M_V = -13,540 \text{ IN LBS (LIMIT)}$$

LOWER R.H. CORNER

$$f_{bV} = \frac{13,540 \times 2.18}{.890} = 33,200 \text{ PSI (LIMIT)}$$

$$f_{bH} = \frac{1400 \times .99}{1.943} = 700 \text{ PSI (LIMIT)}$$

$$F_{TOTAL} = 34,000 \text{ PSI (LIMIT)}$$

$$f_{sH} = \frac{16,000}{1.602} = 10,000 \text{ PSI (LIMIT)}$$

$$f_{sV} = \frac{11,800}{.487} = 24,200 \text{ PSI (LIMIT)}$$

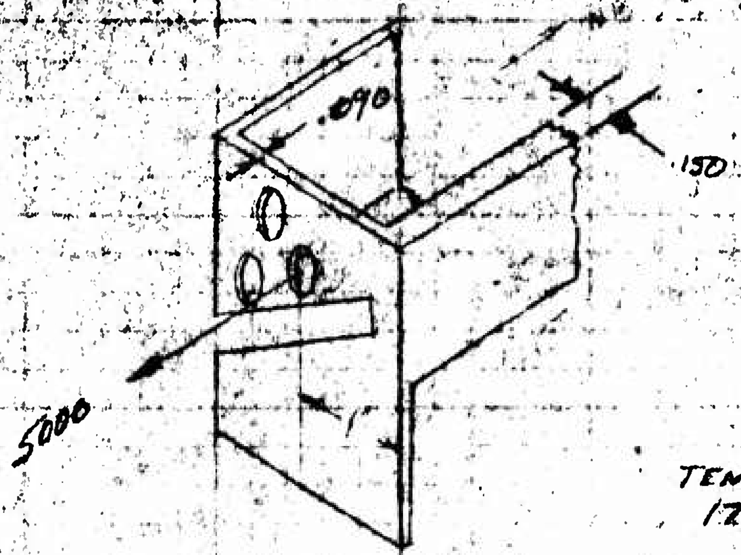
ONLY THE VERICAL WEB WILL BE EFFECTIVE IN CARRYING THE VERTICAL SHEAR LOAD.

$$f_{s\,TOTAL} = 34,300 \text{ PSI LIMIT}$$

MARGINS ARE HIGH

THE 0163 FITTING IS SIMILAR TO THE 0164 AND THE STRESSES WILL BE THE SAME

STRUT ATTACH FITTING



TEMP NEGLECTED
175 °F

CONSIDER THE FITTING AS AN ANGLE TYPE FITTING

A = 1.53 C = .93 B = 1.23 D = .50

$t_e = .090$ $t_N = .150$ $r_i = .187$

$r_o = .381$ $R_1 = .93$ $R_2 = 1.08$

$d = C - D = .93 - .50 = .43$ (REF TENSION TYPE FITTING ANALYSIS)

$a = .93$

$f_{tu} = \frac{5000}{A_g}$ $A_g = \frac{\pi}{2}(1.08^2 - .93^2) = .471$

$f_{tu} = \frac{5000}{.471} = 10{,}600$ PSI ULT

$R_{tu} = \frac{10{,}600}{160{,}000} = .066$

$C = \frac{4}{3\pi} \frac{R_o^2 + R_o R_1 + R_1^2}{R_o + R_1}$

$I = .1098(R_o^4 - R_i^4) - .283 \frac{(R_o^2 R_1^2)(R_o - R_1)}{R_o + R_1}$

$C = .638$ IN.

$I = .046$ IN^4

$M = 5000(.93 - .43) = 2500$ IN LBS

$f_b = \frac{2500 \times .638}{.046} = 34,700$ PSI ULT.

$F_b = 160,000 \times 1.7 = 272,000$ PSI

$R_b = \frac{34,700}{272,000} = .13$ $\quad$ $M.S. = \frac{1}{.13 + .066} - 1 =$ HIGH

END PAD ANALYSIS

$\frac{r_i}{a} = \frac{.187}{.93} = .201$

$\frac{a-d}{r_o} = \frac{.93 - .43}{.281} = \frac{.500}{.281} = 1.78$

* $\frac{t_e}{t_w} = \frac{.135}{.150} = .90$

K_1 (FIG 6) $= 1.86$ $\quad$ (REF TENSION FITTING ANALYSIS.)

K_2 (FIG 7) $= .35$

$f_{bu} = \frac{5000}{.0182} \times 1.86 \times .35 = 178,600$ PSI

$M.S. = \frac{222,000}{178,600} - 1 = \underline{.12}$

* 50% OF RIB WEB ASSUMED ACTING WITH FITTING END WEB

SHEAR OF EAR [illegible]

$f_{s} = \dfrac{5000}{[illegible]} = 31,600$

M.S. $\dfrac{95,000}{31,600} - 1 = 2.00$

$\dfrac{114}{40}$
154

5.2.8 Blade Structure - Station 33 to 63

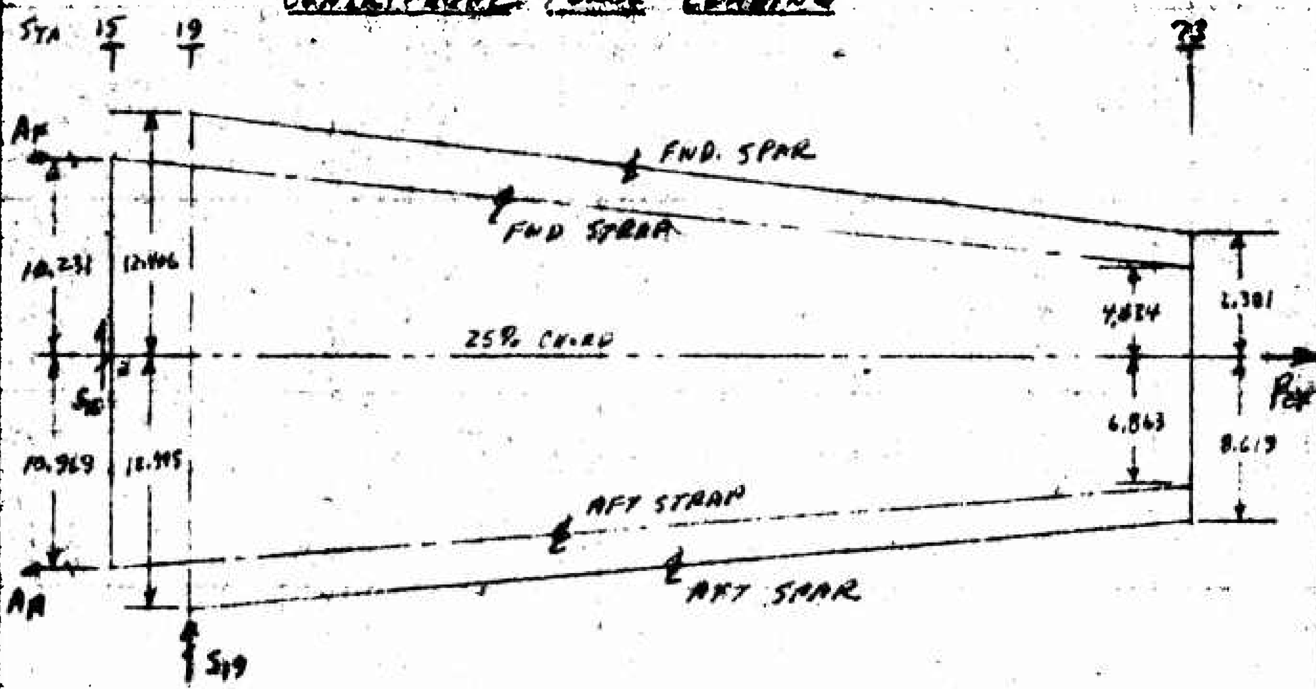
The following analysis pertains to the blade structure for the inboard blade section from Station 33 to the strap-spar fitting structure at Station 63. The structure consists of skin, webs, ribs and flexure ribs and has a removable door at the bottom of the blade from Station 45 to 62. The blade structure is made in two segments which are attached to each other and to the adjacent structure by flexures. Each segment is attached to the spars with four NAS464P4 bolts, two bolts to each spar. The skins and webs are made from 2024-T81 aluminum alloy alclad. The flexures are made from electroformed nickel.

The primary purpose of the blade structure is to provide a torque cell between the blade root section and the strap to spar attachment at Station 63 to 73. The structure is also capable of carrying chordwise shears with the moment produced by the shear being transferred to the spars. The flexure ribs provide a tie between segments that is capable of transferring shear loads but flexible for axial loads and bending moments. The flexures are critical for ultimate stress for droop stop condition instead of cyclic stresses that designed the remaining blade flexures.

BLADE STRUCTURE - STA. 33 TO 63

SPARS & STRAPS - BLADE BALANCE AT 25% C.

CENTRIFUGAL FORCE LOADING



$\Sigma F_H = 0$ $\qquad\qquad$ $\Sigma F_V = 0$

$A_F + A_A = P_{C.F.}$ $\qquad\qquad$ $S_{19} + S_{15} = 0$

Σ Mom @ 0 = 0

$10.231 A_F - 10.969 A_A = -4.00 S_{19}$

$-.09305 A_F + .07029 A_A = -S_{15} = -.0144 P_{C.F.}$

$-A_F + .1608 A_A = 10.747 S_{19}$

$A_F - 1.0721 A_A = -.3916 S_{19}$

$-.3113 A_A = 10.356 S_{19}$ $\qquad$ $A_A = -33.267 S_{19} = .4799 P_{C.F.}$

$A_F = -36.057 S_{19} = .5201 P_{C.F.}$

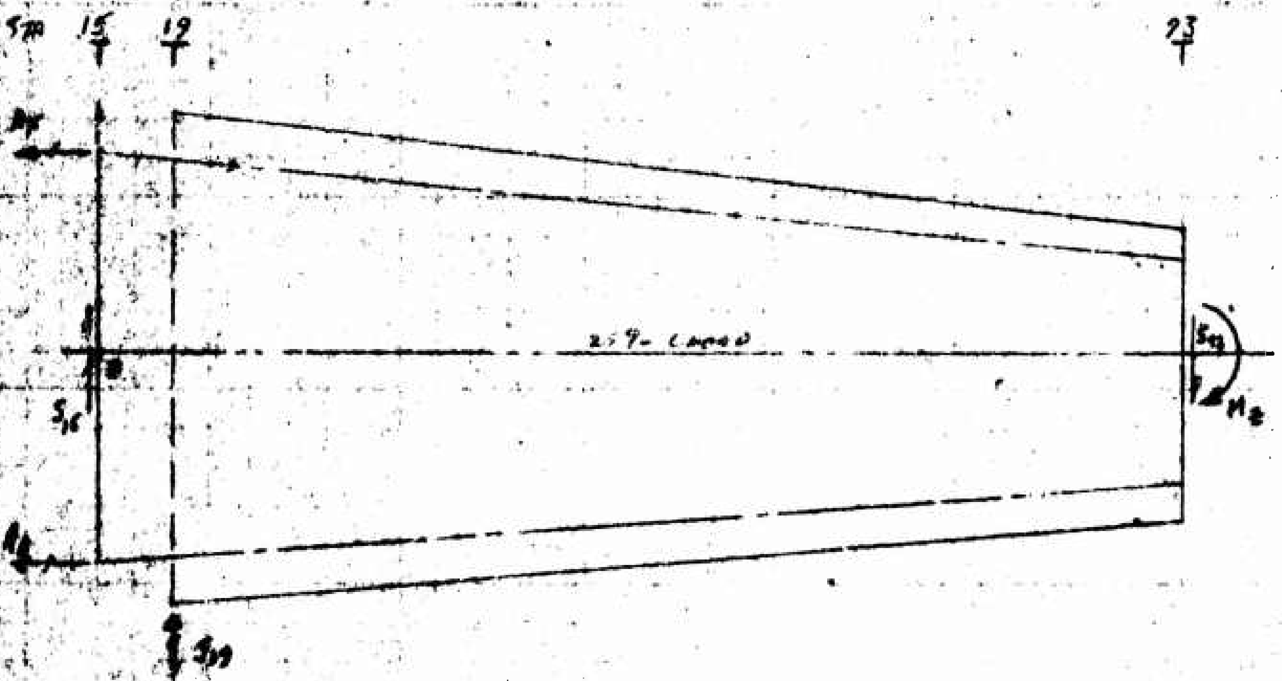
$S_{19} = -.014425 P_{C.F.} = -S_{15}$

ANALYSIS
PREPARED BY J. NEEDHAM 7/22/60
CHECKED BY

BLADE STRUCTURE - STA. 33 TO 73

SPARS & STRAPS - BLADE BALANCED @ 25% CHORD

CHORDWISE SHEAR & MOMENT LOADING



$\Sigma F_H = 0$

$A_F + A_A = 0$

$\Sigma F_V = 0$

$S_{15} + S_{19} = S_{73}$ $\qquad S_{15} = -S_{19} + S_{73}$

ΣM_{OM} @ B $= 0$

$10.431 A_F + 10.769 A_A = -4.00 S_{19} + 58.0 S_{73} + M_Z$

$21.20 A_F = -4.00 S_{19} + 58.0 S_{73} + M_Z$

$S_{15} = .09305 A_F - .07079 A_A = .16384 A_F = -S_{19} + S_{73}$

$A_F = -.1887 S_{19} + 2.7358 S_{73} + .04718 M_Z$

$A_F = -6.1035 S_{19} + 6.1035 S_{73}$

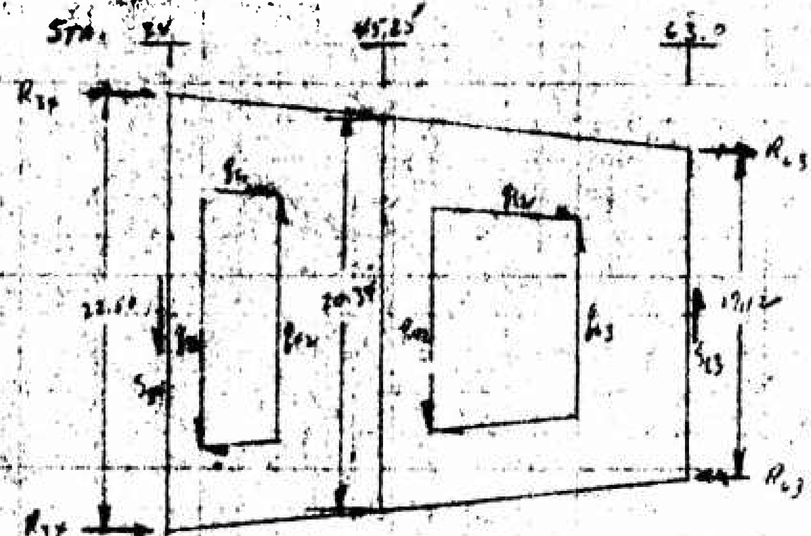
$(-6.1035 + .1887) S_{19} = .04718 M_Z - 3.3677 S_{73}$

$S_{19} = -.00798 M_Z + .5694 S_{73}$

$A_F = .04871 M_Z + 2.628 S_{73} = -A_A$

$S_{15} = .00798 M_Z + .4306 S_{73}$

SKIN SHEAR FLOWS DUE C.F., CHORDWISE SHEAR & MOMENT.



CHORDWISE SHEAR FLOW.

$R_{34} = \frac{15\ S_{19}}{22.50} = .666\ S_{19}$ $\qquad R_{63} = \frac{44\ S_{19}}{17.12} = 2.565\ S_{19}$

$q_{34} = \frac{S_{19}}{2(25.40)}\left(\frac{25.40}{22.50}\right)^2 = .0251\ S_{19}$

$q_{45} = \left(\frac{22.50}{20.34}\right)^2 q_{34} = .0308\ S_{19}$ $\qquad q_{51} = \left(\frac{22.34}{20.34}\right) q_{51} = .0298\ S_{19}$

$q_{13} = \left(\frac{20.34}{17.12}\right)^2 q_{42} = .0472\ S_{19}$ $\qquad q_{34} = \left(\frac{20.34}{17.12}\right) q_{42} = .0365\ S_{19}$

FROM P6's

$S_{19} = .01443\ P_{C.F.} + .00798\ M_{Z_{33}} - .5694\ S_{93}$

WT. FAT. COND.

$P_{C.F.} = 103000^{\#} \quad M_{Z_{33}} = 31000 \pm 60000^{\text{in}\#} \quad S_{93} = 200 \pm 385^{\#}$

$S_{19} = 1488 + 247 \pm 479 - 114 \mp 219 = 1621 \pm 260^{\#}$

Skin Shear Flows Due to C.F., Chordwise Shear & Moment

Wt. Pot. Cond. Cont'd

$q_{34} = .0351 (1121 \pm 260) = 40.7 \pm 6.5$ #/in Lim.

$q_{45} = .0358 (1121 \pm 260) = 50.0 \pm 8.0$

$q_{23} = .0357 (1121 \pm 260) = 40.0 \pm 11.2$

$q_{s_1} = .0278 (1121 \pm 260) = 45.1 \pm 7.2$

$q_{s_2} = .0365 (1121 \pm 260) = 59.1 \pm 9.5$

Over-Rev. Cond.

$P_{CF} = 1.56 \times 103000 = 161000$# $M_{Z_{33}} = 0$ $S_{33} = 0$

$S_{33} = 161000 \times .01443 = 2320$#

$q_{34} = 58.2$ #/in $q_{s_1} = 64.5$ #/in.

$q_{45} = 71.8$ $q_{s_2} = 84.8$

$q_{23} = 103.2$

2½ Man. Cond.

$P_{CF} = 103000$# $S_{33} = 100 \pm 1550$# $M_{Z_{33}} = 10900 \pm 116000$ "#

$S_{CF} = 1488 + 85 \pm 1323 - 52 \mp 881 = 1516 \pm 442$ # Lim.

$q_{34} = 38.1 \pm 11.1$ #/in. $q_{s_1} = 42.1 \pm 12.3$

$q_{45} = 46.9 \pm 13.7$ $q_{s_2} = 55.4 \pm 16.1$

$q_{23} = 65.5 \pm 19.1$

SKIN SHEAR FLOWS FROM TORSION

BLADE TORSION INCLUDING STRAP TORQUE

OVER-REV. T = 26280 "# REF. 1.

2½ G MANEUVER T = 20170 ± 32300 "#

WEIGHTED FATIGUE T = 13100 ± 25190 "#

STA	COND.	2A	qST
34	OVER REV	644	39.7
			—
	2½ g MANV.		30.2 ±47.9
	WT. FAT.		19.4 ±37.3
45.26	OVER REV.	554	48.4
			—
	2½ g MANV.		38.7 ±58.4
	WT. FAT.		23.6 ±45.4
63	OVER REV.	368	72.7
			—
	2½ g MAN.		54.7 ±87.8
	WT. FAT.		35.6 ±68.3

SKIN SHEAR FLOWS — SUMMARY

WEIGHTED FATIGUE CONDITION

$q_{34} = 40.7 \pm 6.5 + 19.4 \pm 37.3 = 60 \pm 44$ #/in.

$q_{45} = 50.0 \pm 8.0 + 23.6 \pm 45.4 = 74 \pm 53$ #/in.

$q_{63} = 70.0 \pm 11.2 + 35.6 \pm 68.3 = 106 \pm 79$ #/in.

2½ g MANEUVER COND.

$q_{34} = 38.1 \pm 11.1 + 30.2 \pm 47.9 = 68 \pm 59 = 127.$ #/in

$q_{45} = 46.9 \pm 13.6 + 36.7 \pm 58.4 = 83 \pm 72 = 155$

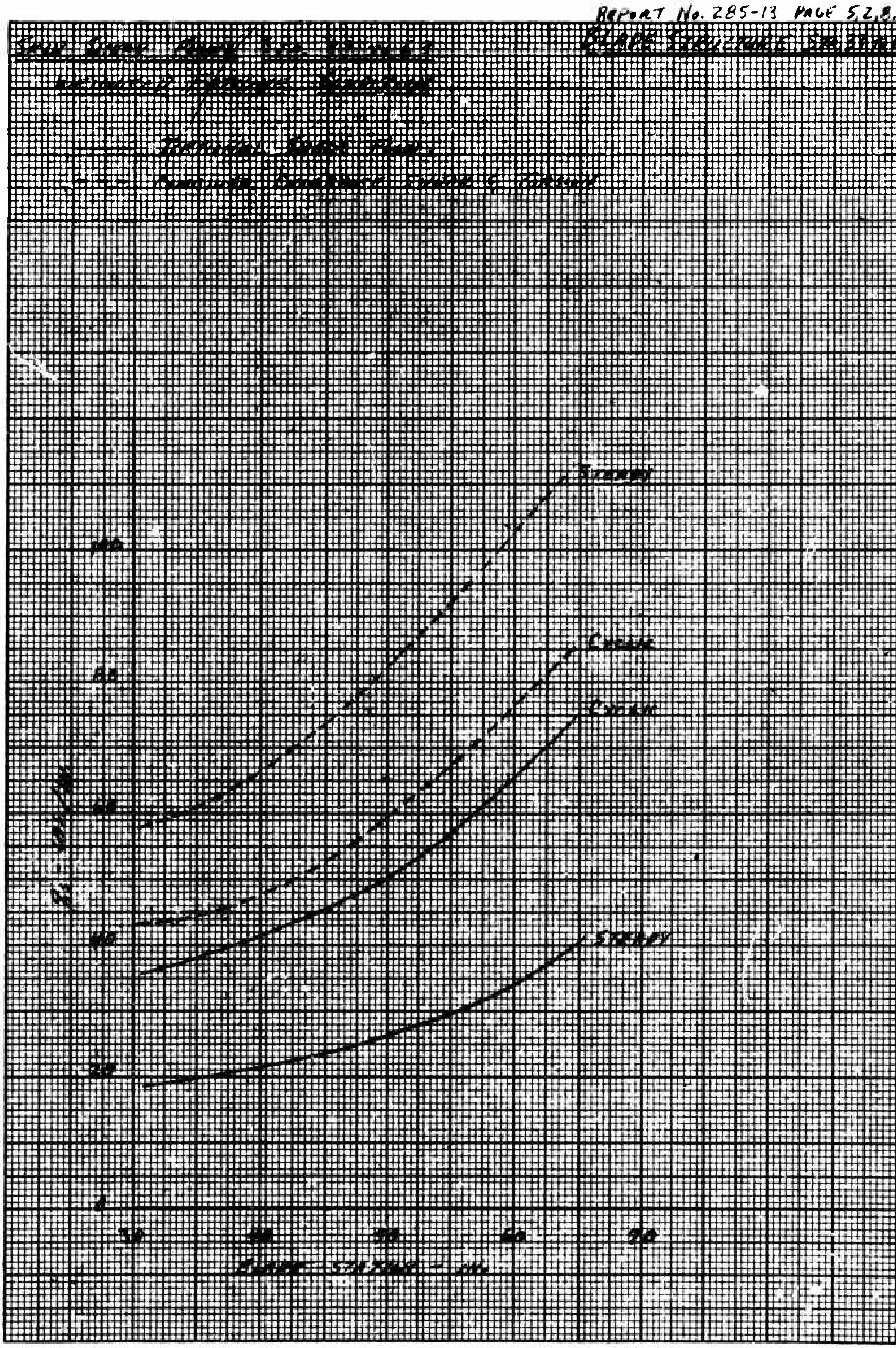
$q_{63} = 45.5 \pm 19.1 + 54.7 \pm 87.8 = 85 \pm 107 = 192$

OVER-REV. CONDITION

$q_{34} = 58.2 + 39.7 = 98.$ #/in.

$q_{45} = 71.5 + 48.4 = 120.$

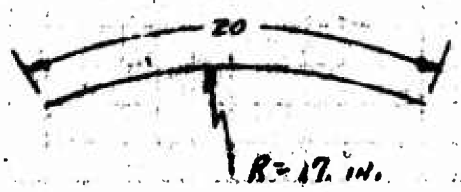
$q_{63} = 100.2 + 72.7 = 173.$


100
80
60
40
20

UPPER SKIN – PANEL STA. 56.3 TO 60.9

PANEL SIZE 4.6 x 20." REF. DWG. 285-0166

MAT'L .050 2024-T3 ALUM. ALC.



ALLOWABLE SHEAR BUCKLING STRESS

$Z = .954 \frac{d^2}{Rt} = \frac{.954(4.6)^2}{17(.050)} = 23.7$ $K_s = 10.5$

$F_{scr}/\eta = 10.5 \times 10.6 \times 10^6 \left(\frac{.050}{4.6}\right)^2 = 13{,}180$ psi $Q_s = 658$ #/in.

MAX. STEADY SHEAR $q = 192$ #/in LIM. (2 ½ g MAN. COND)

$f_s = \frac{192}{.050} = 3840$ psi

M.S. → HIGH

W.F. COND

$q_s = 105 \pm 78$ #/in

$f_s = \frac{105 \pm 78}{.050} = 2100 \pm 1560$ psi

M.S. → HIGH

ATTACHMENT OF SKIN TO FLEXURE WITH AN470 AD5 RIVETS SPACED AT .75" ON CENTER $Q_{allow} = 479/.75 = 640$ LBS/IN.

LOAD ON RIVET = $.75(105 \pm 78) = 79 \pm 58.5$ #/IN

$f_{br} = \frac{79 \pm 58.5}{.159(.050)} = 9950 \pm 7350$ psi

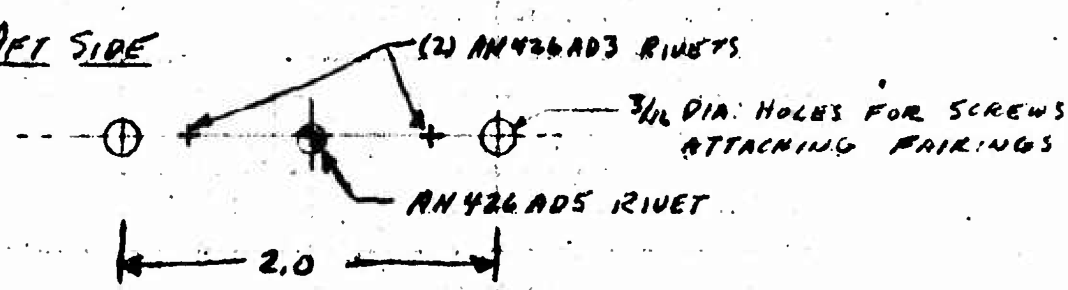
ALLOW. CYCLIC $F_{br} = \pm 7500$ psi

$M.S. = \frac{7500}{7350} - 1 = .02$

UPPER SKIN

ATTACHMENT OF SKIN TO SIDE ANGLES

AFT SIDE



ALLOW. AD5 RIV. MACH CSK IN .050 2024-T3 ALC $P_{br} = 479$ #
ALLOW. AD3 RIV. " " " " " " $P_{br} = 206$ #

$$\text{ALLOW } Q = \frac{479 + 2 \times 206}{2.0} = 445 \text{ \#/IN.}$$

MAX $q_s = 192$ #/IN. LIM., ($2\frac{1}{2}$ g MANU)

$$q_s = (59.1 \pm 9.5) + (35 \pm 67) = 94 \pm 77 \text{ \#/IN. LIM. (W.F. ... STA 61)}$$
$$= (59.1 \pm 9.5) + (31 \pm 58.5) = 90 \pm 68 \text{ \#/IN. LIM. STA 36.4}$$

IF LOAD IS DISTRIBUTED AS A RATIO OF RIVET ALLOWABLES

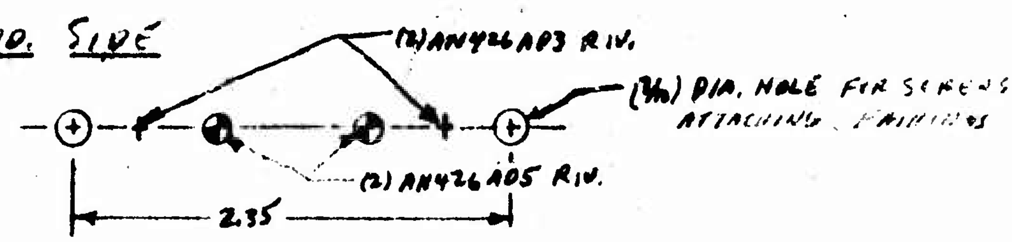
3/32" RIV. $P_{cyc} = \pm 77\left(\frac{206}{891}\right) = \pm 17.8$ # $f_{br} = \frac{17.8}{.094 \times .051} = \pm 3710$ psi

5/32 RIV. $P_{cyc} = \pm 77\left(\frac{479}{891}\right) = \pm 41.4$ $f_{br} = \frac{41.4}{.159 \times .051} = \pm 5100$ psi

ALLOW. CYCLIC $F_{br} = \pm 7500$ psi

$$M.S. = \frac{7500}{5100} - 1 = \underline{.47}$$

FWD. SIDE



$$\text{ALLOW } Q_s = \frac{2(479 + 206)}{2.35} = 667 \text{ \#/IN.}$$

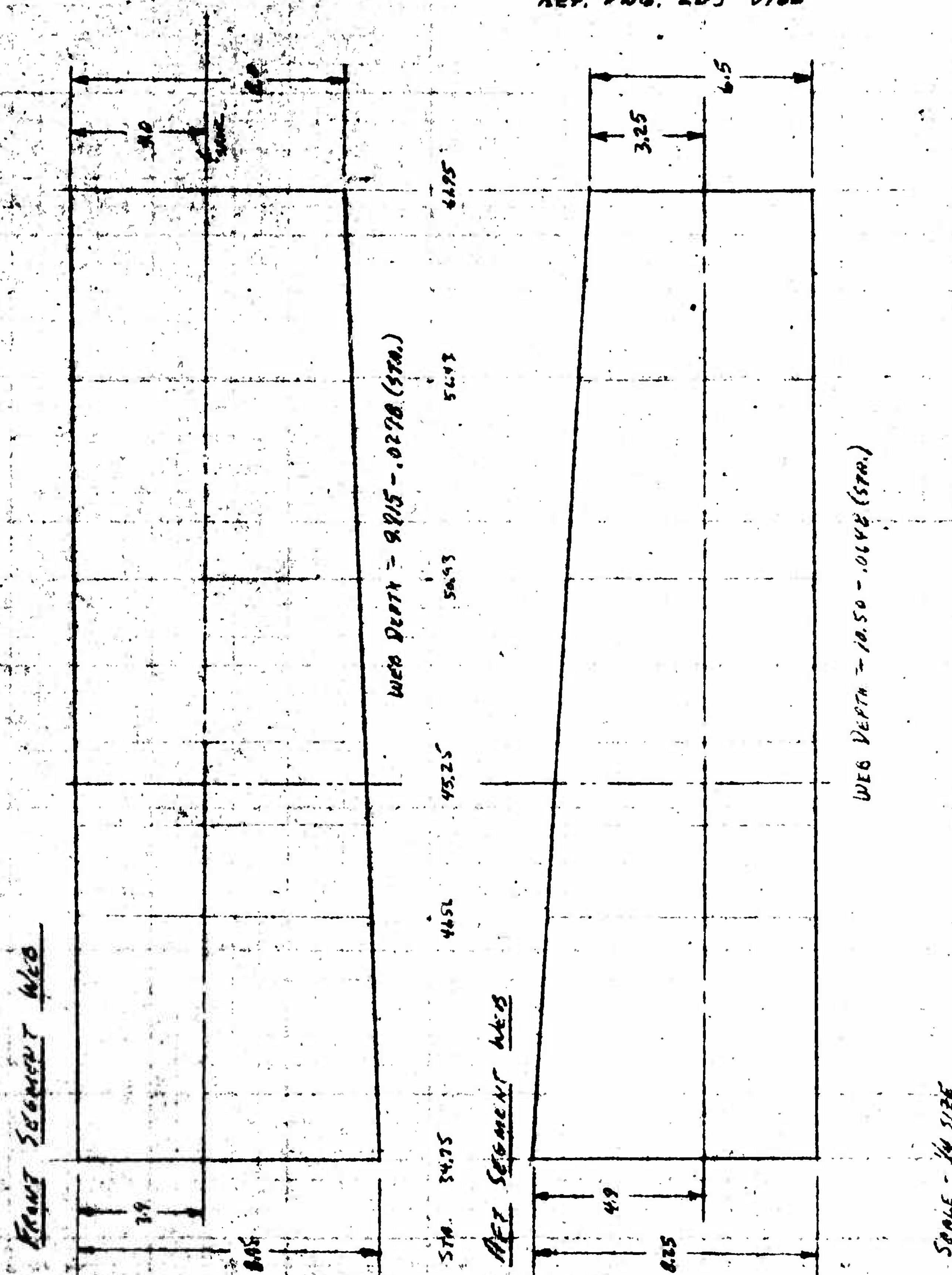
SATISFACTORY BY COMPARISON TO AFT ATTACH ABOVE —

PREPARED BY J. Neyman

BLADE STRUCTURE - STA. 33 TO 63

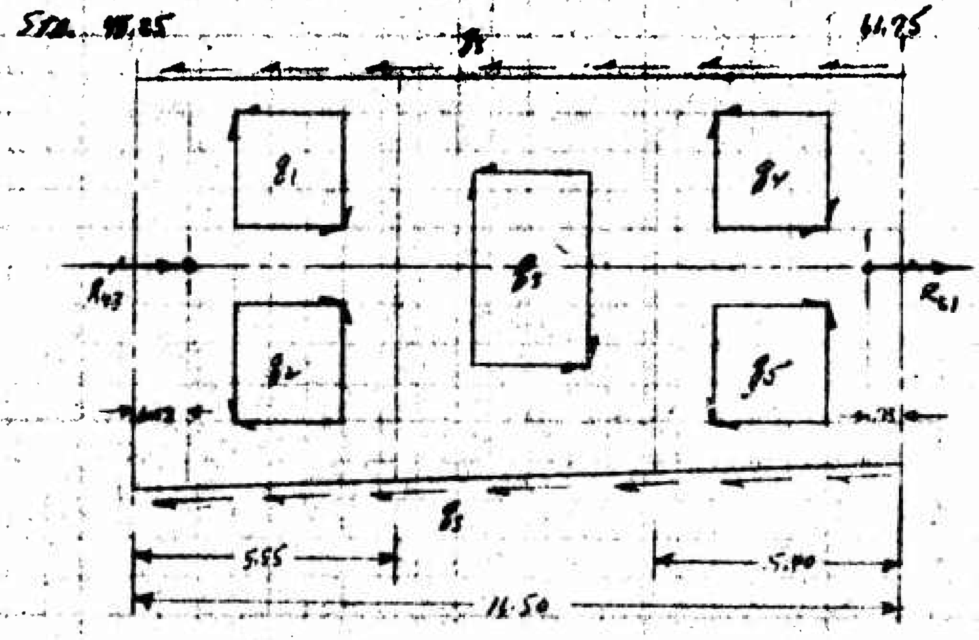
GEOMETRY OF SEGMENT WEBS.

REF. DWG. 285-0166



WEB SHEAR FLOWS

FRONT WEB



let $R_{43} = R_{61} = \frac{2q_3(10.5)}{2.0} = 16.5\,q_3 \qquad q_3 = 0$

$q_1 = \frac{R_{43}}{2(5.55-1.09)} = .1120\,R_{43} = q_2 = 1.85\,q_3$

$q_4 = \frac{R_{61}}{2(5.80-.73)} = .107\,R_{61} = q_5 = 1.765\,q_3$

FOR W.I.F. COND.

$q_{3AVG} = 57.5 \pm 9.2$ #/in. $\qquad R_{43} = R_{61} = 950 \pm 152$ #

$q_1 = 1.85(57.5 \pm 9.2) = 106.4 \pm 17.0$

$q_4 = 1.765(57.5 \pm 9.2) = 101.5 \pm 16.2$

COMBINED WITH TORSION $= q_{3T_{50}} = 26 \pm 30$ #/in $\qquad q_{3_{80}} = 34 \pm 65.5$

$q_1 = 106 \pm 17 + 26 \pm 30 = 132 \pm 47$ #/in $\qquad q_4 = 102 \pm 16 + 34 \pm 66 = 136 \pm 82$ #/in.

$q_2 = 106 \pm 17 - (26 \pm 30) = 80 \mp 13$ #/in $\qquad q_5 = 102 \pm 16 - (34 \pm 66) = 68 \mp 50$ #/in.

$q_3 = 30 \pm 58$ #/in

SEGMENT WEBS

WEB PANEL STA. 58.77 TO 58.43 (CRITICAL PANEL FOR BUCKLING)

W.F. FATIGUE COND.

$q_3 = 30 \pm 58$ #/IN.

$2\frac{1}{2}$ g MANEUVER COND.

$q_3 = 116$ #/IN

$\frac{b}{a} = \frac{5.55}{8.22} = .67 \qquad K_s = 6.98 \qquad E = 10.6 \times 10^6$

$F_{s_{cr}}/\eta = 6.98 \times 10.6 \times 10^6 \left(\frac{.064}{5.55}\right)^2 = 9150 \text{ psi} = F_{s_{cr}}$

$f_{s_{max}} = \frac{116}{.064} = 1820 \text{ psi}$

WEB NON BUCKLING –

WEB ATTACHMENTS

W.F. COND. $q_{s_4} = 30 \pm 58$ LBS/IN.

ATTACHMENT CONSISTS OF AN470 AD5 RIVETS SPACED AT .75 IN. O.C. ALLOW. $Q_s = 596/.75 = 795$ LBS./IN.

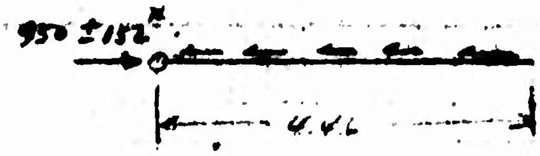
$f_{br} = \frac{30 \pm 58}{.156 \times .064} = 3000 \pm 5800 \text{ psi}$

ALLOW. CYCLIC $F_{br} = \pm 7500$ psi

$M.S. = \frac{7500}{5800} - 1 = .29$

WEB - CONT'D

WEB INTERCOSTAL AT BOLT ATTACH



BOLT BEARING (1/4 BOLT IN .064 2024-T4 ALC + .040 S. STEEL (301 1/4 H)

EFFECTIVE t IN ALUM $= .064 + .040\left(\frac{29\times10^6}{10.5\times10^6}\right) = .167$ IN.

$A_{br} = .167 \times .25 = .0417$ IN.^{2}

$f_{br_{AVG.}} = \frac{950 \pm 152}{.0417} = 22800 \pm 3620$ PSI

$f_{br_{MAX}} = 2(22800 \pm 3620) = 45600 \pm 7240$ PSI

ALLOW. CYCLIC $F_{br} = \pm 7500$ PSI $M.S. = \frac{7500}{7240} - 1 = \underline{.04}$

LOAD IN INTERCOSTAL $= (950 \pm 152)\left(\frac{.103}{.167}\right) = 586 \pm 94$ LBS.

$f_{c_{INTCTL}} = \frac{585 \pm 94}{.040(2.0)} = 7300 \pm 1175$ PSI

SATISFACTORY

ATTACHMENT OF INTERCOSTAL TO WEB

ATTACH CONSISTS OF 11 AN427M5 RIVETS. MACH C'SK IN .064 WEB.

AVG. LOAD PER RIVET $= \frac{950 \pm 152}{11} = 86 \pm 14$#

MAX LOAD PER RIVET $= 172 \pm 28$#

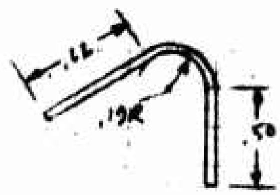
ALLOWABLE OF A 5/32 AD RIVET MACH. C'SK IN .063 2024-T3

$P_{br} = 523$#

SATISFACTORY

BLADE STRUCTURE - STA. 53 TO 63

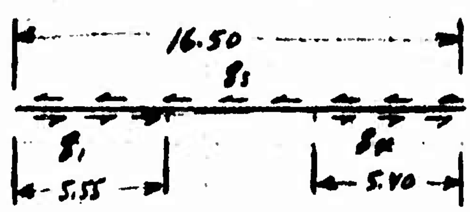
CAP ANGLE ATTACHING SKIN & WEB



$A = .064 \times 1.50 = .096$ IN.^{2}

MAT'L .064 2024-T4 CLAD ALUM.

W.F. COND. LOADING.



$q_s = 57.5 \pm 9.2$ #/IN.

$q_1 = 106.4 \pm 17.0$ #/IN.

$q_2 = 101.5 \pm 16.2$ #/IN.

$$\text{MAX LOAD} = 5.55\left[106.4 \pm 17.0 - (57.5 \pm 9.2)\right] = 271 \pm 43 \ \#$$

$$f_c = \frac{271 \pm 43}{.096} = 2820 \pm 450 \text{ psi LIM. (BASED ON GROSS AREA)}$$

SATISFACTORY

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

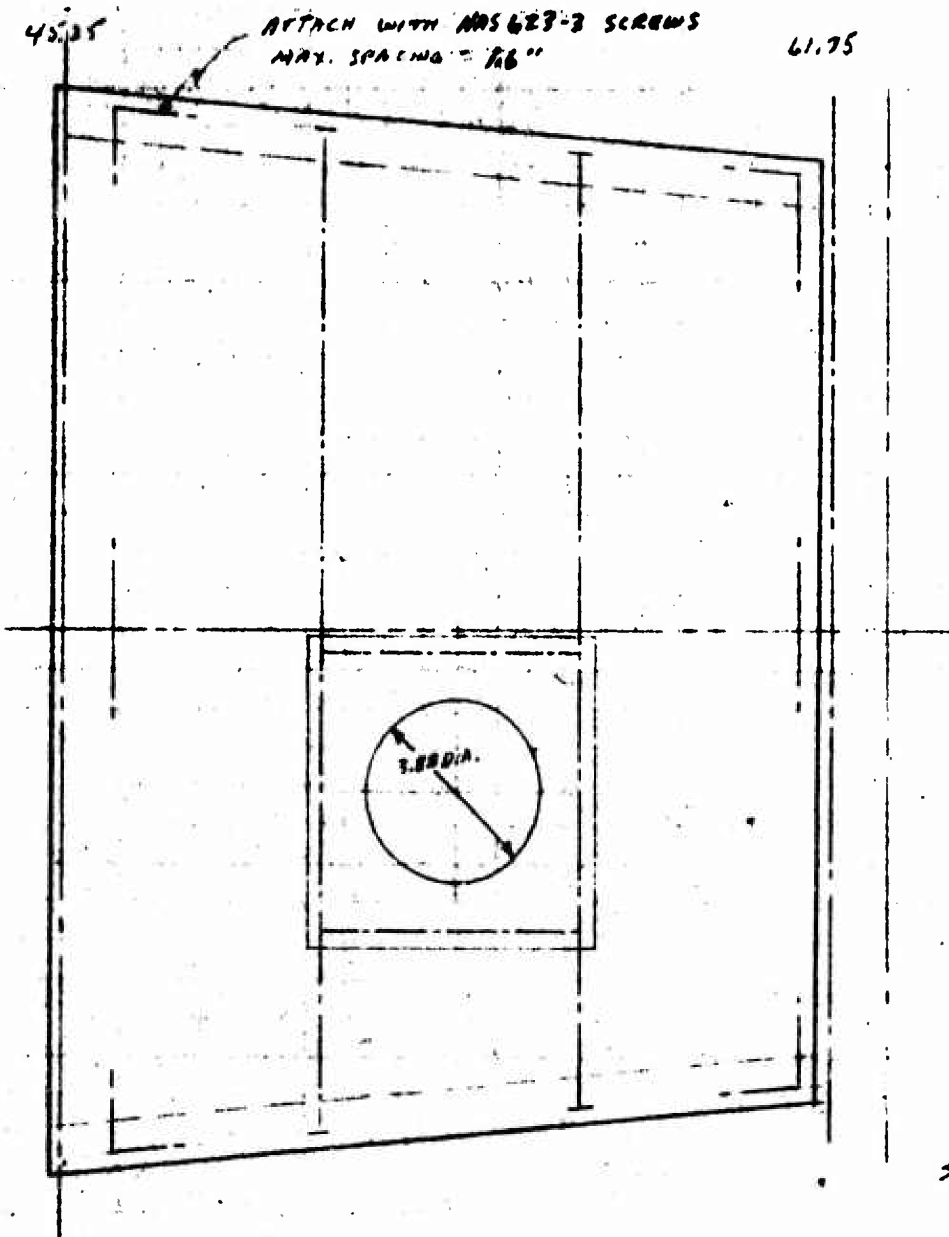
ANALYSIS
PREPARED BY J. Neighman 7/28/60
CHECKED BY

MODEL 285 REPORT NO. 285-13 PAGE 5.2.8.16

BLADE STRUCTURE - STA. 33 TO 63

DOOR - STA. 45 TO 61 BOTTOM SURFACE

REF. DWG. 285-0166



SCALE - 1/4 SIZE

DOOR -

ATTACHMENT OF DOOR TO BLADE STRUCTURE

ATTACHMENT TO FLEXURE @ STA. 61

NAS 623-3 SCREWS SPACED AT 1.60" O.C.

SCREW BEARS IN -5 SKIN & -9 DOUBLER BOTH .051 2024-T3 ALC.
AND IN ELECTROFORM NICKEL FLEXURE $t = \frac{.138}{.033}$ (DWG -0197-3)
PLUS -73 DOUBLER ($t = .051$ 2024 T-3 ALC)

$q_s = 105 \pm 78$ #/IN (W.F. COND.)

f_{br} (SKIN & DOUBLER) $= \frac{1.60 (105 \pm 78)}{.187 (.102)} = 7950 \pm 5900$ psi

ALLOW. CYC. $F_{br} = \pm 7500$ psi   M.S. $= \frac{7500}{5900} - 1 = \underline{.27}$

EFFECTIVE t OF FLEXURE TO ALUM $t_e = .051 + .073 \left(\frac{29}{10.5}\right) = .142$

$f_{br} = \frac{105 \pm 78}{.197 (.142)} = 5900 \pm 4240$ psi

LESS CRITICAL THAN SKIN & DOUBLER

LOAD TRANSFER - FLEX. TO DOUBLER $\Delta q_s = \left(\frac{.051}{.142}\right)(105 \pm 78) = 37.7 \pm 28.0$

$f_{br} = \frac{37.7 \pm 28.0}{.159 \times .051} = 4650 \pm 3460$ psi.

LOAD TRANSFER FROM SKIN TO DOUBLER

$\Delta q_s = \frac{105 \pm 78}{2} = 53 \pm 39$ #/IN.

ATTACH OF SKIN TO DOUBLER - MS20426 AD4 RIVETS SPACED AT .80 IN. O.C.

$f_{br} = \frac{.80 (53 \pm 39)}{.128 (.051)} = 8300 \pm 6110$ psi

ALLOW. CYCLIC $F_{br} = \pm 7500$ psi

M.S. $= \frac{7500}{6110} - 1 = \underline{.22}$

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

MODEL 285 REPORT NO. 285-13 PAGE 5.2.8.18

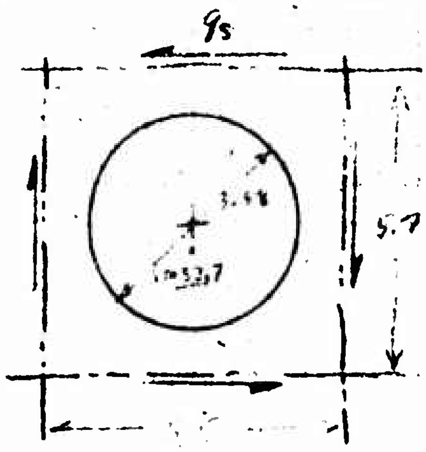
ANALYSIS —

PREPARED BY J. NEEDHAM 4/28/60 | BLADE STRUCTURE – STA. 33 TO 63

CHECKED BY

DOOR

3.88 DIA HOLE @ STA. 53.7 FOR OUTFLOW OF COOLING AIR.



SKIN t=.051 2024 T3 CLAD ALUM.

DOUBLER t=.051 [illegible] T3 ALC.

W.F. COND.

$q_{AVG} = 90 \pm 66$ #/IN.

SHEAR STRESS ON SKIN NO HOLE OR DOUBLER

$$f_s = \frac{90 \pm 66}{.051} = 1765 \pm 1294 \text{ psi}$$

WITH DOUBLER – NO HOLE

$$f_s = 882 \pm 647 \text{ psi}$$

BASED ON NET AREA

$$f_s = \left(\frac{5.5}{5.5 - 3.88}\right)(882 \pm 647) = 3000 \pm 2200 \text{ psi}$$

1.62

CONCENTRATION FACTOR PER – NACA [illegible]

$$\beta = \frac{3.88}{5.5} = .705 \qquad \beta^2 = .497 \qquad \beta^3 = .350$$

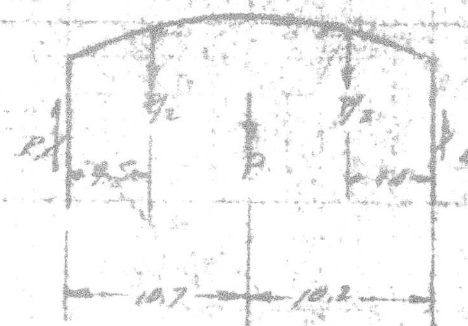
$$\overset{\circ}{F} = 2.000 + 4.21(.705) - 7.46(.497) + 12.5(.35) = 7.6[illegible]$$

$$\text{MAX } f_s = 7.62\,(882 \pm 647) = 6730 \pm 4940 \text{ psi}$$

BLADE STRUCTURE - STA. 33 TO 63

FRAME STA. 41.36

UNIT FRAME LOADING



FRAME MAT'L
.064 2024-T4 CLAD ALUM.

$R_2 = \dfrac{P/2 \times 4.5 + 16.9 \times P/2}{20.9} = .512P$

$R_1 = .488\,P$

BENDING MOMENT ON FRAME

STA FROM LEFT (IN.)	M+	M-	M TOTAL
1	.488 P		.488 P
2	.976 P		.976 P
3	1.464 P		1.464 P
4	1.952 P		1.952 P
4.4	2.147 P		2.147 P
5.0	2.440 P	-.75 P	1.690 P
6.0	2.928 P	-1.455 P	1.473 P
7.0	3.416 P	-2.15 P	1.266 P
8.0	3.904 P	-2.80 P	1.104 P
9.0	4.392 P	-3.40 P	.992 P
10	4.88 P	-4.00 P	.880 P
11	5.319 P	-4.40 P	.919 P
12	5.807 P	-4.80 P	.957 P
13	6.295 P	-5.25 P	1.045 P
14	6.783 P	-5.60 P	1.183 P
15	7.271 P	-5.950 P	1.321 P
16	7.759 P	-6.250 P	1.509 P
17	8.247 P	-6.250 P	1.997 P
18	8.735 P	-7.250 P	1.485 P
19	9.223 P	-8.250	.998 P
20	9.711 P	-9.250	.461 P
21	10.199 P	-10.25 P	0

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

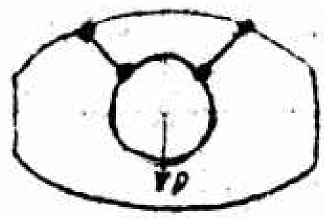
MODEL 285 REPORT NO. 285-13 PAGE 5.2.8.20

ANALYSIS
PREPARED BY J. NEEDHAM 7/29/40
CHECKED BY

BOOM STRUCTURE - STA. 33 TO 63

FRAME STA. 41.56

FRAME AT STA 41.56 SUPPORTS THE DUCT SEAL SUPPORTING BOTH THE OUTBOARD END OF THE INBOARD DUCT AND THE INBOARD END OF THE OUTBOARD DUCT.



FROM ANALYSIS OF DUCTS

W.F. COND. $P = 178 \pm 24 \left(\frac{22.0}{15.8}\right)(30 \pm 15) = 214 \pm 20^{\#}$ LIMIT

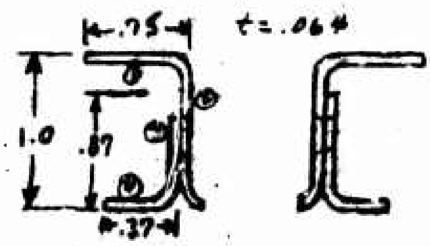
$2\frac{1}{2}g$ COND. $P = 444^{\#}$ LIMIT

FROM UNIT FRAME ANALYSIS

MAX. $M_{M} = 2.147 (214 \pm 20) = 460 \pm 43$ IN. LBS

$2.147 (444) = 955$ IN. LBS.

SECTION [illegible] MAX. MOM.



ITEM	A	Z	AZ	AZ²	I_o
1	.048	.032	.0015	—	
2	.064	.500	.0320	.0160	.0053
3	.052	.530	.0276	.0146	.0045
4	.024	.970	.0233	.0226	
Σ	.188	-	.0844	.0532	.00[illegible]

$\bar{z} = \frac{.0844}{.188} = .449''$ $I_{NA} = 2(.0628 - .188(.449)^2) = .050 \text{ in}^4$

$f_b = \frac{(460 \pm 43).55}{.050} = 5060 \pm 470$ psi LIM.

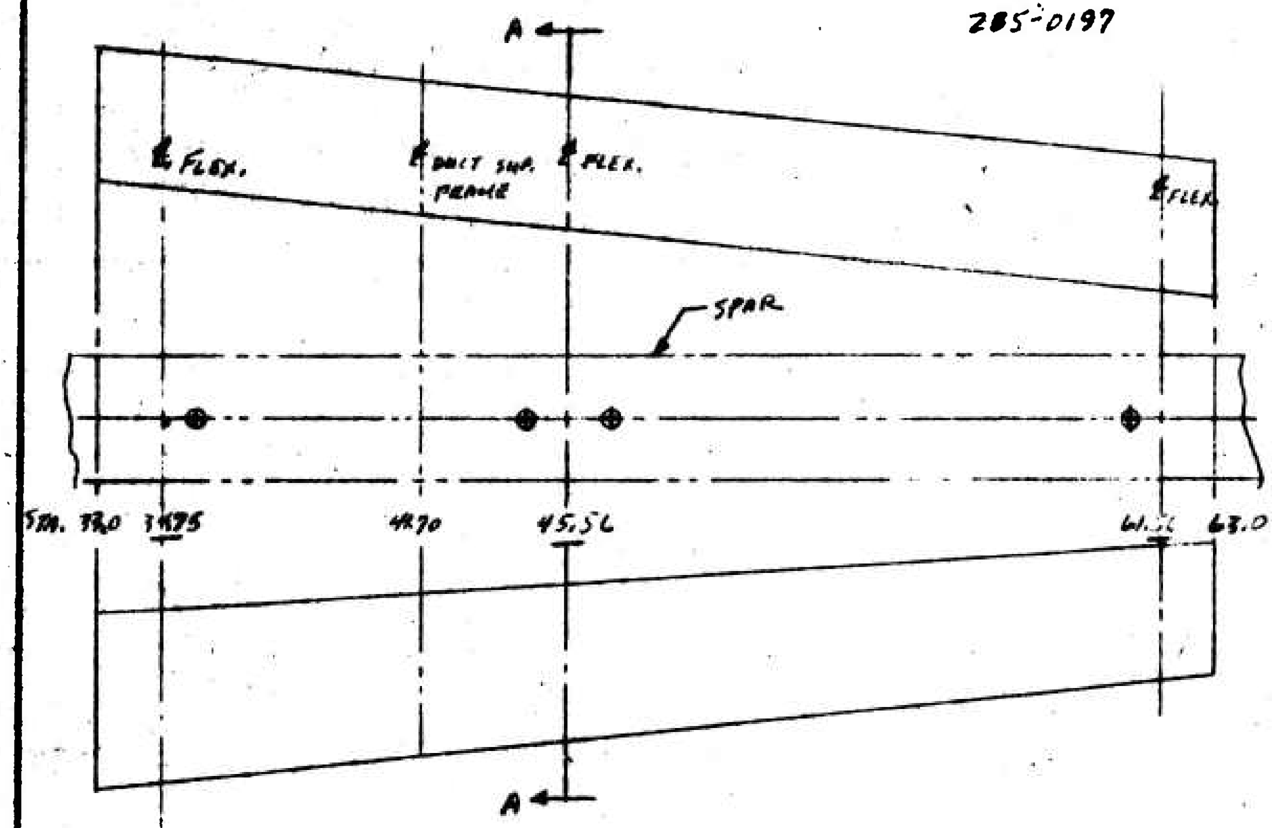
$f_{b_{max}} = \frac{955 \times .55}{.050} = 10500$ psi LIMIT

FRAME IS SATISFACTORY —

1.00
.45
1.55

BLADE FLEXURE LOCATIONS

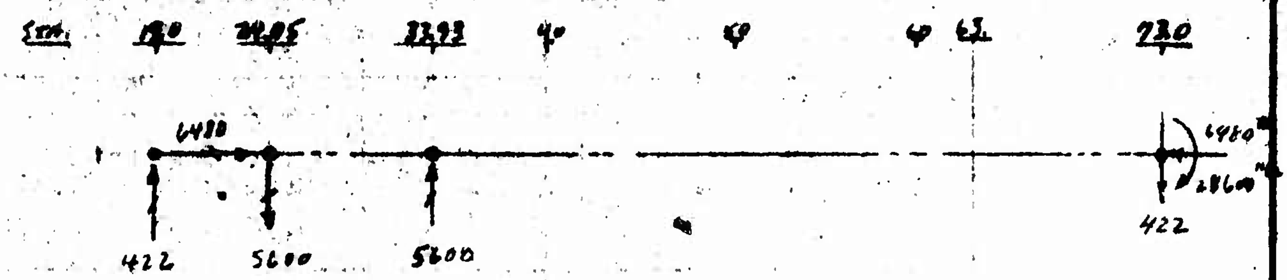
REF. DWG. 285-0166
285-0197

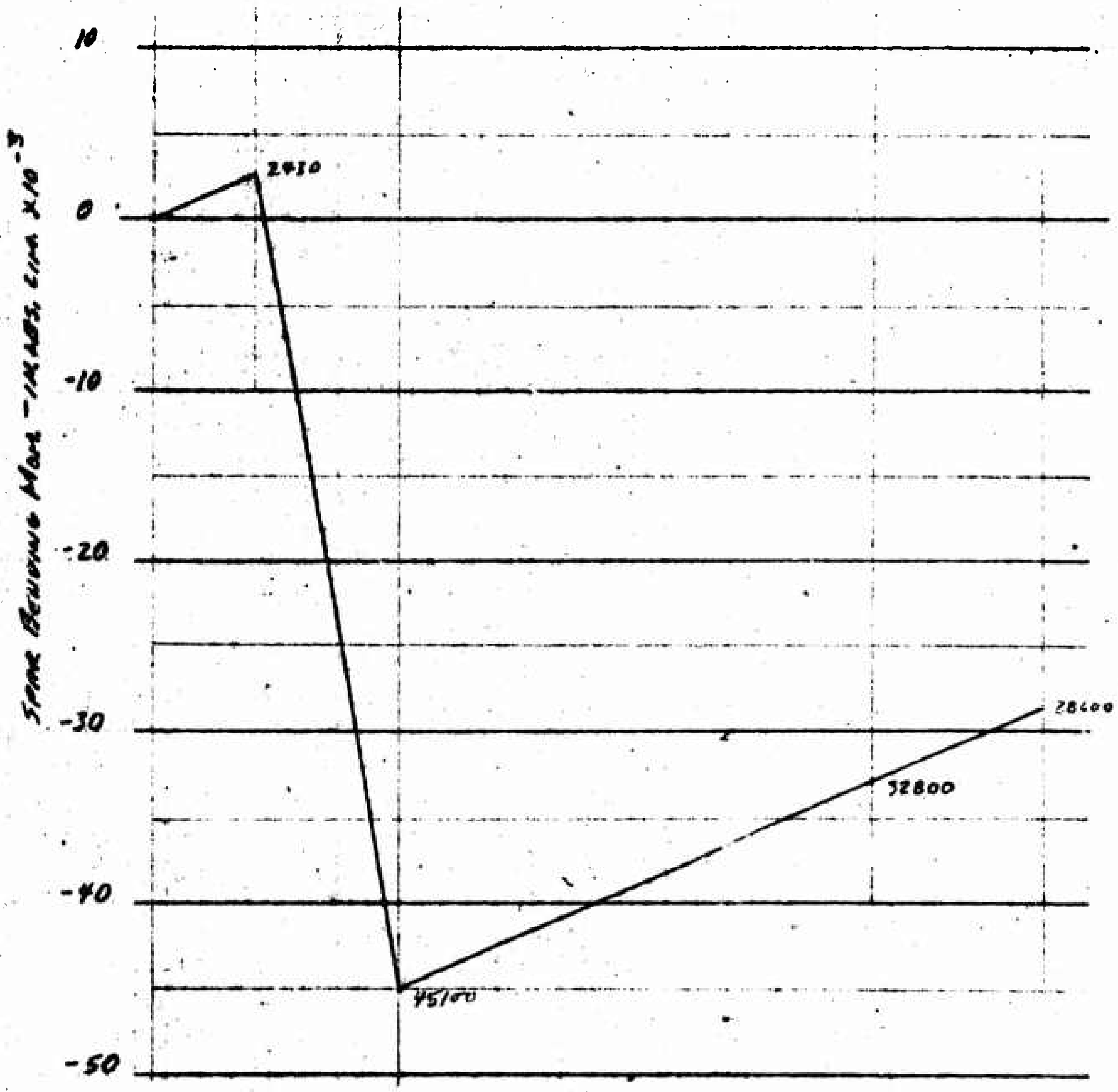


⊕ NAS464P4 BOLTS ATTACHING BLADE SEGMENTS TO SPARS.

FLEXURES

BLADE LOADS FOR DROOP STOP LOADING @ 1g.





HUGHES TOOL COMPANY – AIRCRAFT DIVISION

ANALYSIS ____ MODEL 285 REPORT NO. 285-13 PAGE 5.2.8.23

PREPARED BY J. [illegible] [illegible]

CHECKED BY ____

BLADE STRUCTURE – STA. 33 TO 65

DEFLECTION CURVE OF SPARS – STA. [illegible] TO STA. [illegible]

FOR 1g [illegible] LOADS

I of [illegible] SPARS = [illegible] = 2.50 in^4

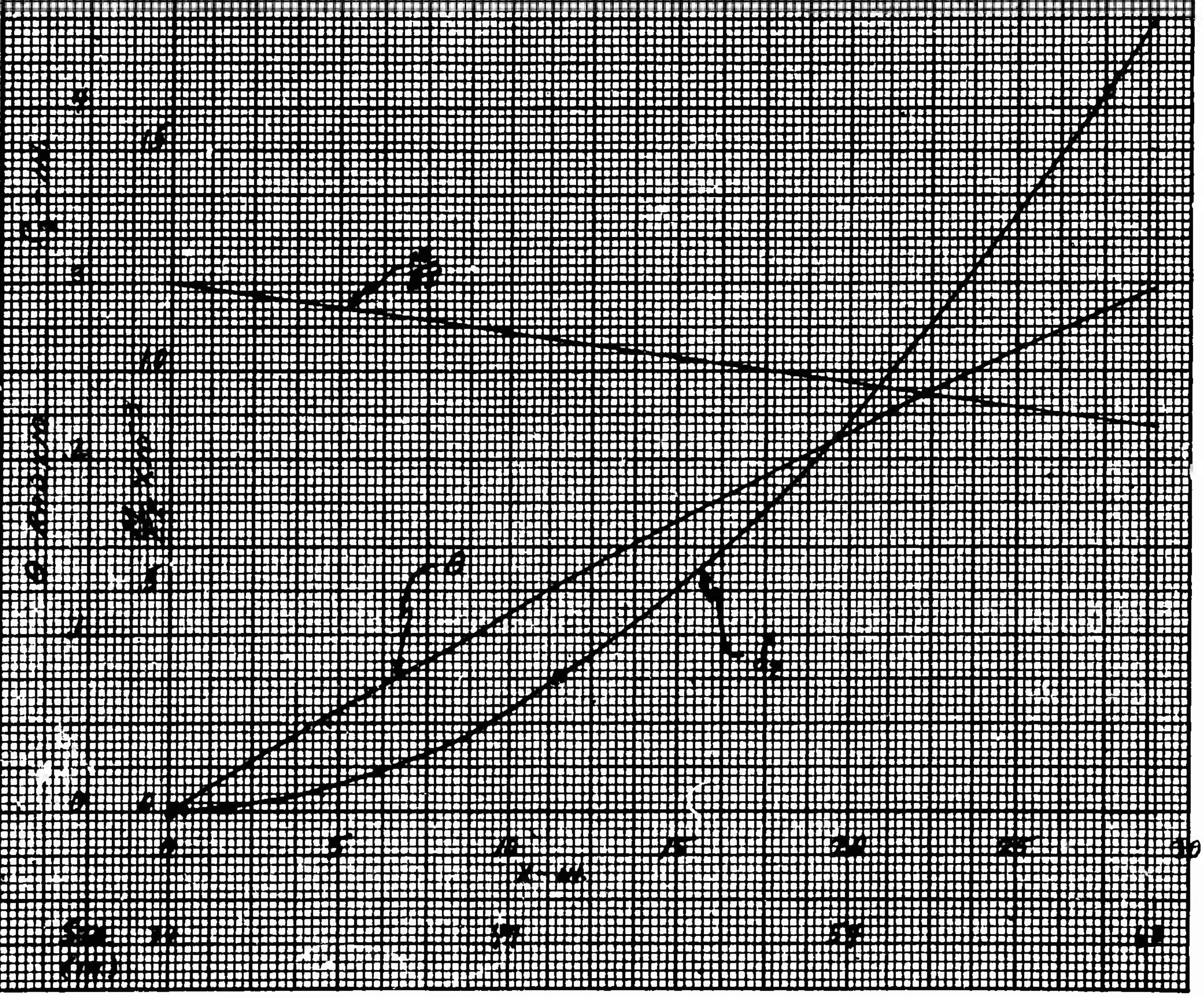
E = [illegible] $\times 10^6$ (SPAR MAT'L IS TITANIUM)

STA. 33 M/EI = [illegible] = .120 $\times 10^{-3}$

STA. 63 M/EI = 37800/[illegible] = .875 $\times 10^{-3}$

1g [illegible] ROTATION at FLEXURE @ STA. 45.5

θ = [illegible]/16.0 = [illegible]/19.5 = .0138 RAD.

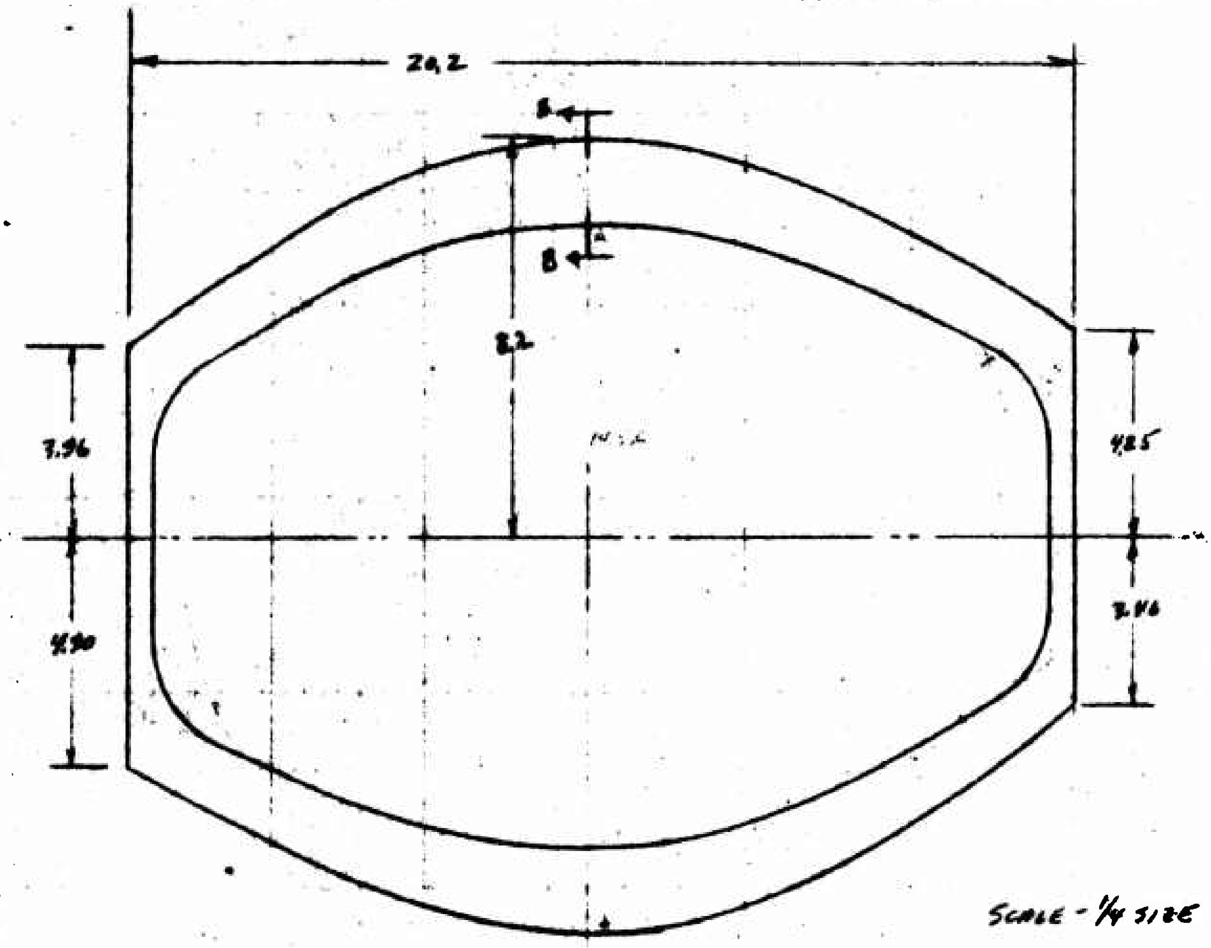


HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS	MODEL 285 — REPORT NO. 285-13 — PAGE 5.2.8.24
PREPARED BY J. NEEDHAM 4/16/60	BLADE STRUCTURE - STA. 33 TO 63
CHECKED BY	

FLEXURE STA. 45.5

REF. DWG. 285-0197



SCALE - 1/4 SIZE

SECT. A-A FROM PG. 5.2.8.21

INCLOSED AREA OF INNER SIDE OF FLEXURE

$1.5 \times 11.8 = 19.5$
$3.4 \times 10.8 = 36.7$
$3.4 \times 12.7 = 43.2$
$3.5 \times 12.7 = 44.4$
$3.55 \times 10.6 = 37.6$
$2.9 \times 7.5 = 21.8$
$A = 203.2$

$2A = 406 \text{ in}^2$

TORQUE AREA OF SKIN & WEBS
$A = 276 \qquad 2A = 552 \text{ in}^2$

SHEAR FLOWS BASED ON INNER SIDE OF FLEXURE
WT. FATIGUE COND.

CHORD SHEAR $q_{SC} = 955 \pm 315 / 20.2 = 47 \pm 16$ LBS/IN.
TORQUE SHEAR $q_{ST} = 13100 \pm 25100 / 406 = 32. \pm 62$ LBS/IN
$q_{S MAX} = 79 \pm 78$ LBS/IN.

FLEX. $t = .019$ $\qquad f_S = \dfrac{79 \pm 78}{.017} = 4650 \pm 4600$ PSI

2784

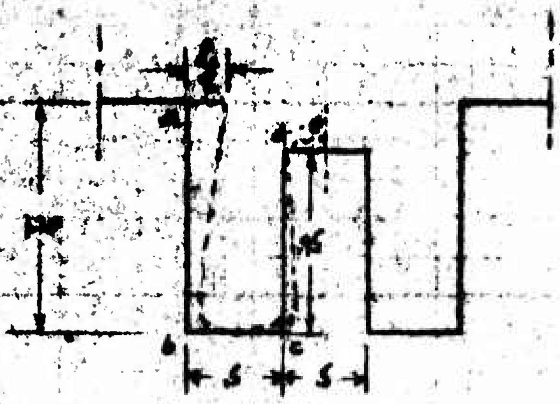
HUGHES TOOL COMPANY-AIRCRAFT DIVISION

MODEL 285 REPORT NO. 285-13 PAGE 52.8.25

PREPARED BY J. NEEDHAM 6/28/60

BLADE STRUCTURE - STA. 33 TO 63

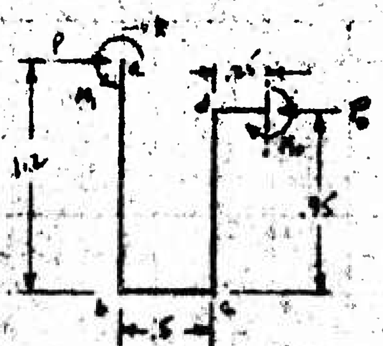
FLEXURE STA. 45.5



MAT'L - ELECTROFORM NICKEL

$t_{min} = .017$ IN.

SECT. B-B REF. PG. 52.8.24



LET $M_1 = \frac{1.20P}{2} = .6P$

$M_0 = M_1 - .25P = .60P - .25P = .35P$

$b \to d \quad M = -.60P + Pz \qquad m = -.6 + z$

$d \to e \quad M = .35P \qquad m = .35$

$a \to b \quad EI\delta_x = .0833(1.20)^3 P = .1440P$

$b \to c \quad EI\delta_x = .250(.50)(1.20)^2 P = .1800P$

$c \to d \quad EI\delta_x = P\int_0^{.95}(z-.6)^2 dz = \frac{P}{3}\left[(z-.6)^3\right]_0^{.95} = .0864P$

$d \to e \quad EI\delta_x = P\int_0^{.25}(.35)^2 dx = P(.35)^2(.25) = .0306P$

$a \to e \quad EI\delta_x = 2(.1440P + .1800P + .0864P + .0306P) = .882P$

FOR 2½ g GROUND FLAPPING CONDITION

$\delta_{x_{max}} = 2.5 \times 6.2 \times .0138 = .28 \qquad E = 30 \times 10^6 \qquad t = .017$

$P = \frac{EI\delta_x}{.882} \quad M_{max} = .60P \quad f_b = \frac{6M}{t^2} = \frac{3.6\,EI\delta_x}{.882\,t^2}$

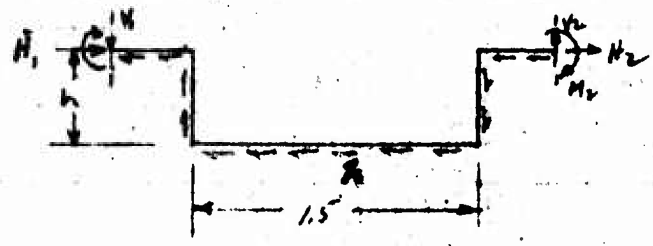
$f_b = \frac{3.6(30 \times 10^6)(.0833 t^3)(.28)}{.882\ t^2} = 48500$ psi

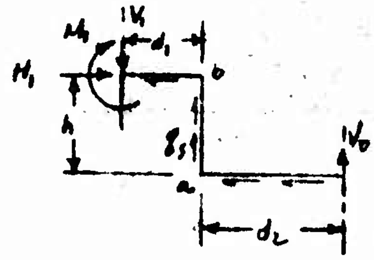
$F_{ty} = 50000$ psi

$M.S. = \frac{50000}{48500} - 1 = \underline{.03}$

FLEXURE STA. 45.5 @ SPAR ℄

FLEXURE BENDING MOMENTS DUE TO CHORDWISE SHEAR FLOW.





$$H = q_s(d_1 + d_2)$$

$$V_1 = V_0 + h q_s$$

$$M_1 = h q_s d_1 + V_0(d_1 + d_2) - d_2 h q_s$$
$$= V_0 d + h(d_1 - d_2) q_s$$

$$V_0 = \left[\frac{\left(\frac{d_2^2 h}{2} - \frac{h d_1^3}{3} + h d_2^2 d_1\right)}{\left(d_2^2 h + \frac{(d_1+d_2)^3}{3}\right)}\right] q_s$$ (FROM AN UNIT LOAD SOLUTION)

$h = .50 \quad d_1 = .40 \quad d_2 = .75$

$$V_0 = \left[\frac{\frac{(.75)^2(.50)}{2} - \frac{(.50)(.40)^3}{3} + (.50)(.75)^2(.40)}{(.75)^2(.50) + \frac{(1.15)^3}{3}}\right] q_s = \frac{.1722}{.788} q_s = .2185 q_s$$

$$V_1 = .2185 q_s + .50 q_s = .7185 q_s$$

$$M_1 = (.50)(.40) q_s + .2185 q_s (1.15) - (.75)(.50) q_s = .0765 q_s$$

$$M_b = .0765 q_s - .7185 q_s (.400) = -.2110 q_s$$

$$M_a = -.2110 + (1.15 - .40).50 q_s = .1640 q_s$$

$$M_0 = .164 q_s - (.7185 - .500).75 q_s \cong 0 = 0 \checkmark$$

FLEXURE STA. 45.5 @ SPAR ℄

WEIGHTED FATIGUE COND.

CHORDWISE SHEAR	$q_{b_s} = 47 \pm 16$	#/IN
TORSION	$q_{s_T} = 24 \pm 45$	#/IN.
TOTAL	$q_s = 71 \pm 61$	#/IN.

FLEX. SHEAR BENDING STRESS DUE TO CHORDWISE CYCLIC SHEAR. EFFECTIVE DEPTH OF FLEX. FOR RESISTING CHORDWISE SHEAR COUPLE = 2.0 IN.

$$M_{b_s} = .211\, q_s = .211\,(16) = \pm 3.38 \text{ IN-\#} \qquad t = .035$$

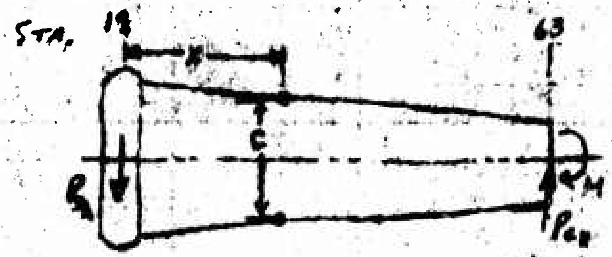
$$f_{b_{s\,max}} = \frac{6M}{2.0t^2} = \frac{6(\pm 3.38)}{2(.035)^2} = \pm 8300 \text{ psi}$$

SECTION IS SATISFACTORY

FLEXURE STA 45.5

CHORDWISE BLADE ROTATION

CHORDWISE B. MOMENTS



2 1/2 g MANEUVER $P_{CH} = 3900$ #

W. FATIGUE $P_{CH} = 1910 \pm 630$

SPAR AXIAL LOAD $P_C = \frac{P_{CH}\,x}{C}$

@ STA. 45.5

$2\frac{1}{2}g \quad P_C = \frac{3900 \times 26.25}{20.3} = 5050$ #

SPAR AREA $= .936\ in^2$

$f_c = \frac{5050}{.936} = 5400$ psi

SPAR DEFL @ FLEX.

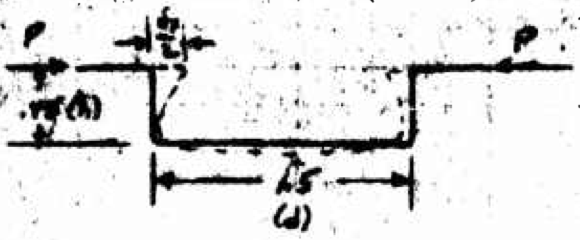
$\delta_x = \frac{5400 \times 13.43}{15 \times 10^6} = .0048$ IN.

FATIGUE COND.

$\delta_x = .0048 \left(\frac{1910 \pm 630}{3900}\right) = .0024 \pm .00078$

FLEXURE STA. 45.5 @ SPAR ℄

STRESSES DUE TO SPAR DEFLECTION.



$t = .035$

MAT'L - ELECTROFORM NICKEL

$2\frac{1}{2}$ g MAN. COND $\delta_x = .0048''$

WT. FATIGUE COND. $\delta_x = .0024 \pm .00078''$

FROM GENERAL STRAIN-ENERGY SOLUTION:

$$f_b = \frac{.250\, t\, E\, \delta_x}{[.1667 h^2 + .250 d h]} = \frac{.250(.035)(30 \times 10^6)\, \delta_x}{[.1667(.05)^2 + .250(1.5)(.05)]} = 1.295 \times 10^6\, \delta_x$$

$2\frac{1}{2}$ g MANV. COND.

$f_b = 1.295 \times 10^6 (.0048) = 6200$ psi

WT. FATIGUE COND.

$f_b = 3100 \pm 1010$ psi

FLEXURE STA. 34.68 & 61.56

FLAPWISE ROTATATION OF FLEXURES AT SPAR ℄
FOR 1g LOADING

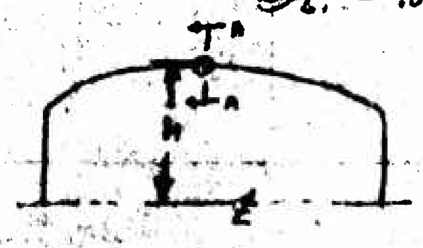
STA. 34.68 $\theta_{34} = .00690$ RAD.

STA. 61.56 $\theta_{61} = .0285 - .208 = .0077$ RAD.

FOR 2½ g LOADING

$\theta_{34} = .01725$ RAD

$\theta_{61} = .0192$ RAD



$h_{34} = 9.4$ REF. DWG. 285-0197

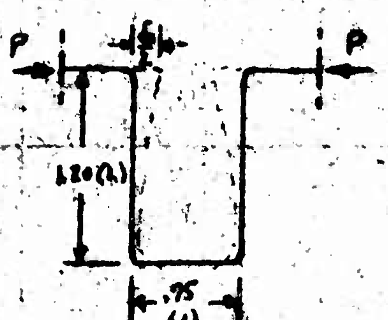
$h_{61} = 6.7$

$\delta_x = h\theta$

$\delta_{x_{34}} = 9.4 \times .01725 = .161''$

$\delta_{x_{61}} = 6.7 \times .0192 = .129''$

SECTION A-A (STA. 34.0)



FROM STRAIN ENERGY ANALYSIS OF FLEXURE

$$f_b = \frac{.250\, t\, E\, \delta_x}{[.1667 h^2 + .250 dh]}$$

$t = .019$ $E = 30 \times 10^6$ $\delta_x = .161$

$$f_b = \frac{.250(.019)(30\times10^6)(.161)}{[.1667(1.2)^2 + .250(.75)(1.20)]} = 44000 \text{ psi}$$

$F_{ty} = 50000$ psi

$$M.S. = \frac{50000}{44000} - 1 = \underline{.13}$$

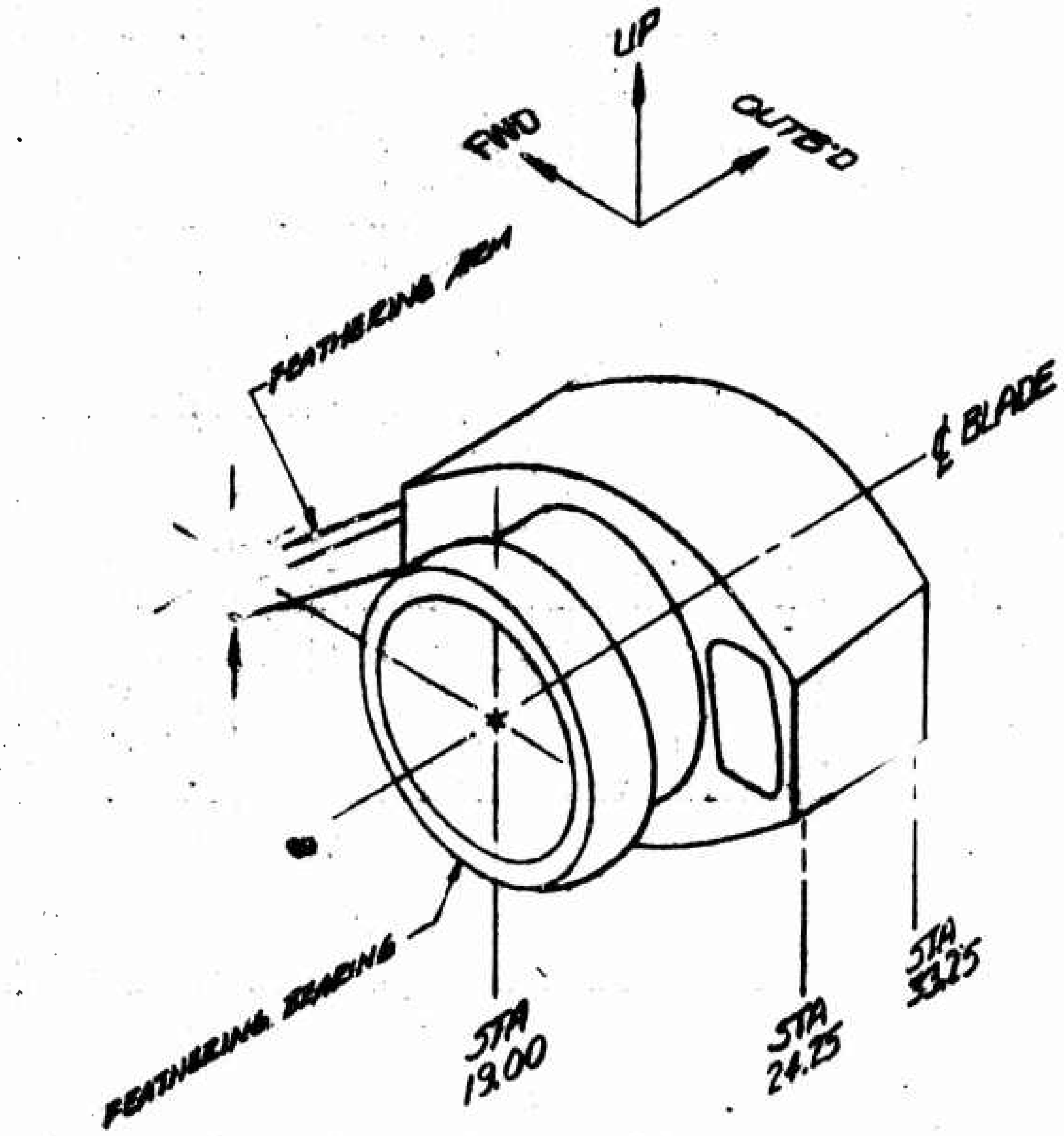
5.2.9 INBOARD TORQUE BOX STA 19-33

THE INBOARD TORQUE BOX COMPRISES THE ROTOR BLADE ROOT STRUCTURE. TO THIS STRUCTURE ARE MOUNTED THE BLADE FEATHERING BEARINGS AND THE FEATHERING ARM.

THE STRUCTURE CONSISTS OF TWO RIBS LOCATED AT BLADE STATIONS 24.25 & 33.25, WHICH SERVE AS CLOSING MEMBERS OF THE BOX. THE "INNER WALL" OF THE BOX IS AN OBLONG TUBE WHICH ALSO SERVES AS THE MOUNTING STRUCTURE FOR THE FEATHERING BALL. THE "OUTER WALLS" OF THE BOX CONSIST OF UPPER AND LOWER SKINS AND VERTICAL WEBS FORE AND AFT. INTERIOR STRUCTURE IS MADE UP OF SKIN STIFFENERS AND INTERCOSTALS. ALSO INCLUDED ARE A DROOP STOP FITTING AND BACK-UP STRUCTURE.

LOADS ARE APPLIED TO THE STRUCTURE FROM THE FEATHERING ARM OR FROM THE OUTB'D BLADE STRUCTURE. DROOP STOP LOADS ARE REACTED AT THE DROOP STOP FITTING.

INBOARD TORQUE BOX



INBOARD TORQUE BOX

5.2.9.1 WEIGHTED FATIGUE CONDITION LOADING ANALYSIS

IN THE WEIGHTED FATIGUE CONDITION, THE MAXIMUM LOAD APPLIED TO THE STRUCTURE IS APPLIED AT THE FEATHERING ARM:

$$P_A = 819 \pm 1732 \text{ \# LIMIT}$$

(REF CONTROL LOADS TABLE 5.4.2.2-2)

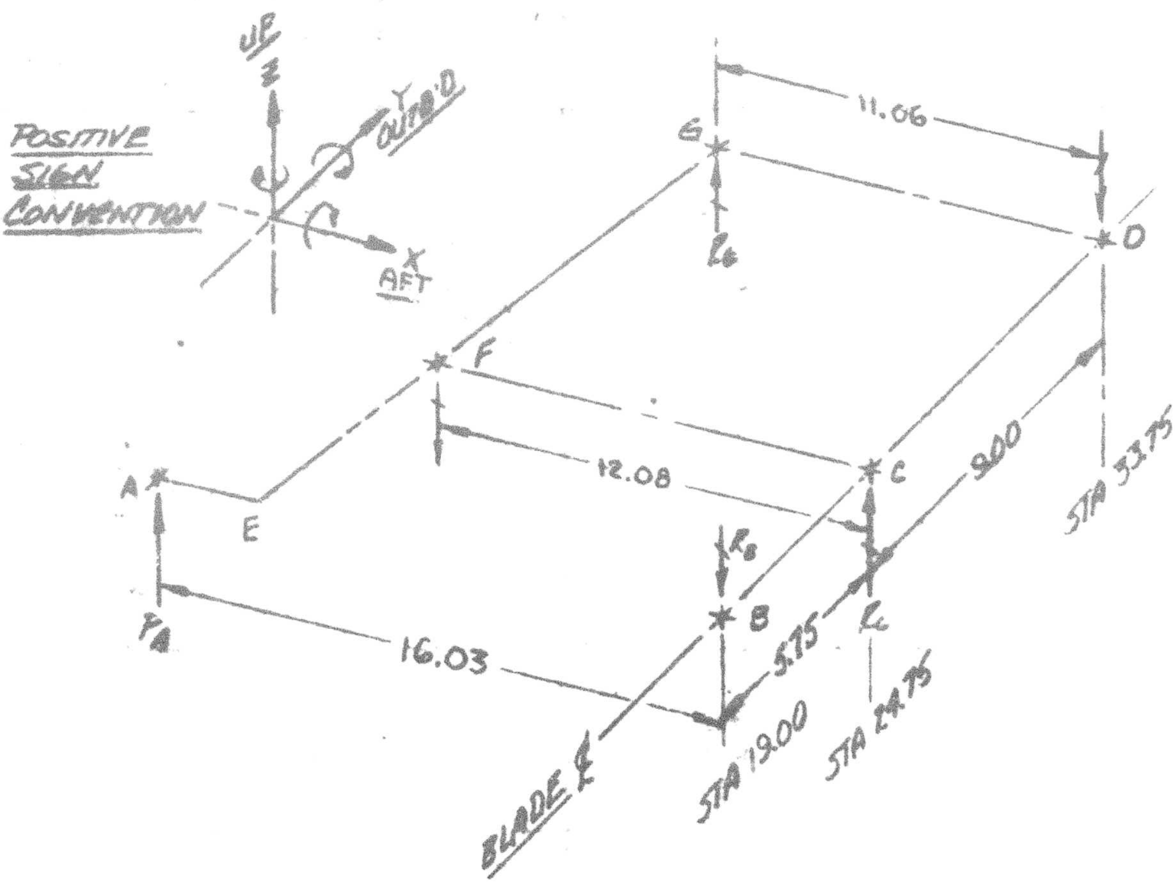
FOR THE ANALYSIS, A UNIT FORCE SOLUTION IS USED IN DETERMINING THE FATIGUE STRESSES IN THE RIBS. A LOADS AND STRESSES SUMMARY FOR THE STA. 24.25 RIB APPEARS ON PAGE 5.2.9.2.16 THE ANALYSIS OF THE STATION 33.25 RIB DETERMINES THE FATIGUE STRESSES IN THE BODY OF THAT ANALYSIS.

FASTENERS ANALYSIS APPEARS ON PAGE 5.2.9.4.0

FEATHERING ARM ANALYSIS APPEARS ON PAGE 5.2.9.5.0

ROTOR BLADE

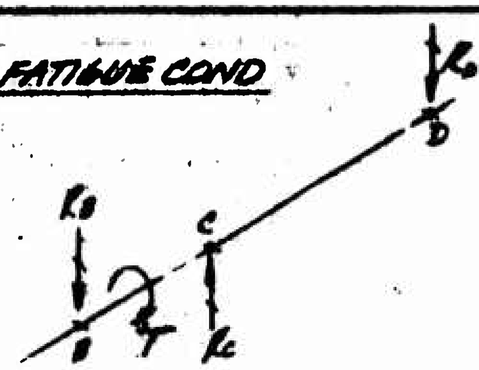
INBOARD TORQUE BOX — WEIGHTED FATIGUE CONDITION



METHOD - LOADS APPLIED TO THE FEATHERING ARM.

A UNIT FORCE SOLUTION WHERE P_A = 1000 LBS WILL BE USED IN THE ANALYSIS.
STA 24.75 & STA 33.75 REPRESENT STATION OF RIB TO SKIN ATTACHMENTS. ALL DIMENSIONS GIVEN BASED ON THESE STATION LOCATIONS.

INBOARD TORQUE BOX WEIGHTED FATIGUE COND



REACTIONS ALONG BLADE ℄

POINT B

$R_B = P_A = 1000\#$

$T_A = 1000(16.03) = 16,030''\#$

T_A = APPLIED TORQUE

POINT C

$\sum M_{X_D} = 0 = 1000(14.75) - R_C(9.00)$

$R_C = 1640\#$

$R_B = 1000\#$

$T_A = 16,030''\#$

$R_C = 1640$

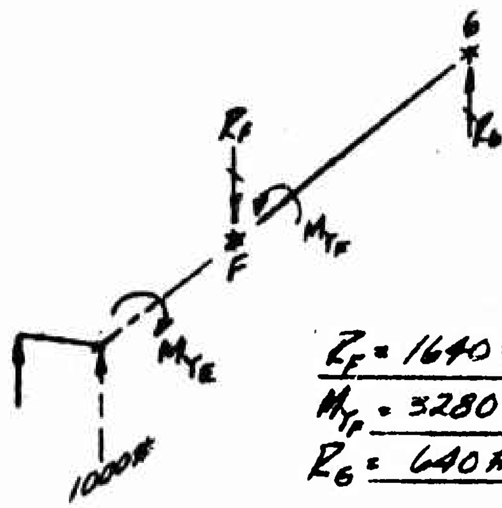
$R_D = 640$

POINT D

$\sum Z = 0 = 1000 - 1640 + R_D$

$\therefore R_D = 640\#$

REACTIONS ALONG E-F-G



POINT F

$R_F = -R_C = 1640\#$

$M_{Y_F} = -M_{Y_E} = 1000(3.28) = 3280''\#$

POINT G

$R_G = -R_D = 640\#$

$R_F = 1640\#$

$M_{Y_F} = 3280''\#$

$R_G = 640\#$

RIB TORQUES (APPLIED)

STA 24.25 RIB

$T_C = -R_F \times 12.08 - M_{YF}$

$= (1640)(12.08) - (-3280)$

$T_C = 23030''\#$

STA 33.25 RIB

$T_D = -R_G \times 11.06$

$= (-640)(11.06)$

$T_D = -7080''\#$

<u>INBOARD TORQUE BOX</u> <u>WEIGHTED FATIGUE COND</u>

<u>LOAD DISTRIBUTION TO RIBS</u> –

CONSIDER SECTION AS A TORQUE BOX CONSISTING OF 2 TUBES WHERE THE TUBES TWIST EQUALLY –

$$\theta_1 = \theta_2 = \theta_{TOTAL}$$

WHERE

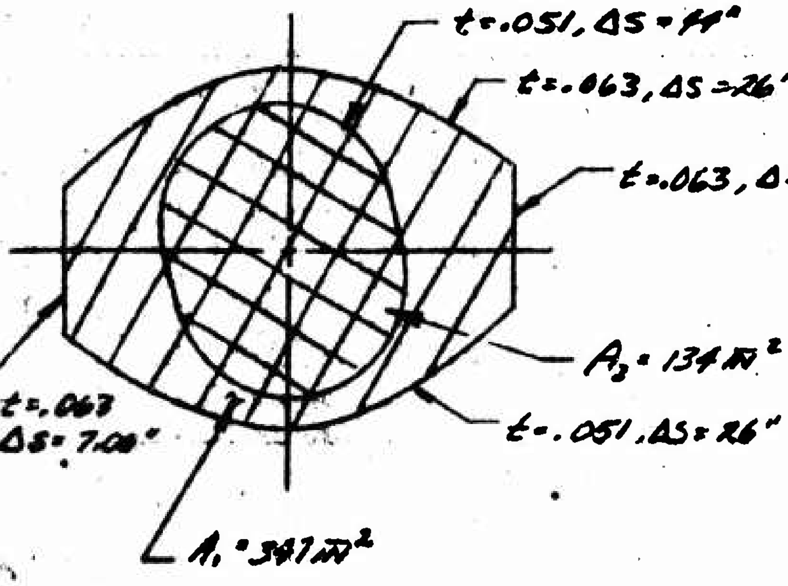
$$\theta = \Sigma \frac{2q\Delta s L}{2AG} = \frac{T\Sigma\frac{\Delta s}{t}}{4A^2} \quad \text{(REF 3, CHAP 16, PG 448)}$$

(BOTH L & G SAME FOR θ_1 & θ_2)

AND $\frac{4A^2}{\Sigma\frac{\Delta s}{t}} = J$ SO THAT $\frac{T_1}{J_1} = \frac{T_2}{J_2} = \frac{T_{TOTAL}}{J_{TOTAL}}$

$$J_{TOTAL} = J_1 + J_2$$

TAKING AN AVERAGE SECTION BETWEEN THE RIBS –



$$J_1 = \frac{4A_1^2}{\Sigma\frac{\Delta s_1}{t_1}} = \frac{4(347)^2}{\frac{26}{.063}+\frac{7}{.063}+\frac{26}{.051}+\frac{7}{.063}} = 488 \text{ in}^4$$

$$J_2 = \frac{4A_2^2}{\Sigma\frac{\Delta s_2}{t_2}} = \frac{4(134)^2}{\frac{44}{.051}} = 83 \text{ in}^4$$

$$J_{TOTAL} = J_1 + J_2 = 571 \text{ in}^4$$

INBOARD TORQUE BOX UNWEIGHTED FATIGUE COND

5.2.9.2 RIB STA 24.25

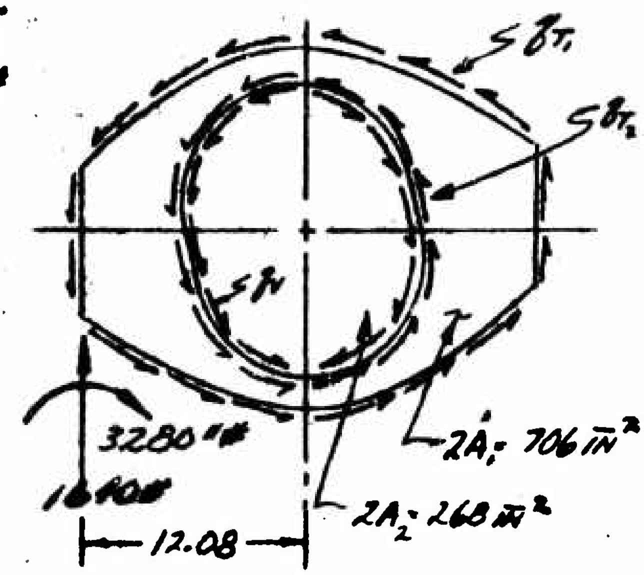
$T_{TOTAL} = 3280 + 1640(12.08) = 23080\,''\#$

$T_1 = \frac{T_{TOT}\,J_1}{J_{TOT}} = \frac{(23080)(488)}{571}$

$T_1 = 19730\,''\#$

$T_2 = \frac{T_{TOT}\,J_2}{J_{TOT}} = \frac{(23080)(83)}{571}$

$T_2 = 3350\,''\#$



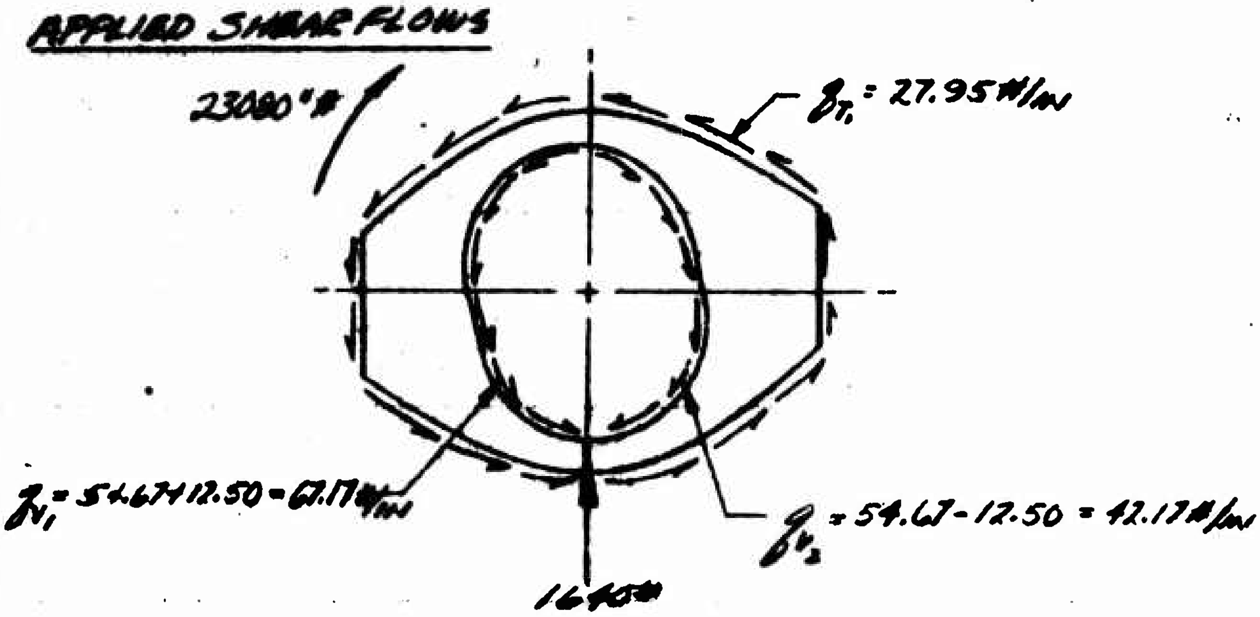
ASSUMING A CONSTANT q_V RESISTING 1640# —

$q_V = \frac{V}{2h} = \frac{1640}{2\cdot 15} = 54.67$ $q_V = 54.67\#/in$

$q_{T_1} = \frac{T_1}{2A_1} = \frac{19730}{706} = 27.95$ $q_{T_1} = 27.95\#/in$

$q_{T_2} = \frac{T_2}{2A_2} = \frac{3350}{268} = 12.50$ $q_{T_2} = 12.50\#/in$

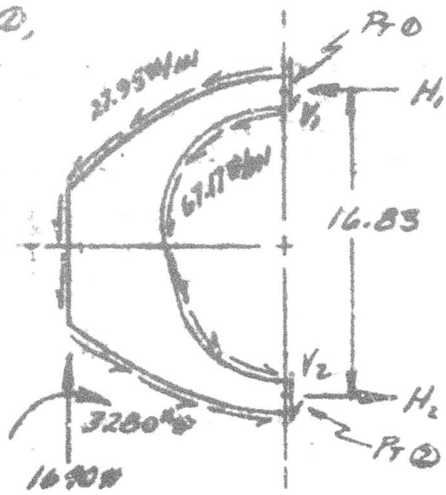
APPLIED SHEAR FLOWS



INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

RIB - STA 24.25

ASSUMING A POINT OF INFLECTION @ POINT ①, AN ANALYSIS WILL BE MADE OF THE FWD HALF OF THE RIB, THE AFT PORTION TO BE CHECKED BY INSPECTION



THE AFT PORTION SHEAR FLOWS ARE REPRESENTED BY THE HORIZONTAL AND VERTICAL LOADS AS SHOWN.

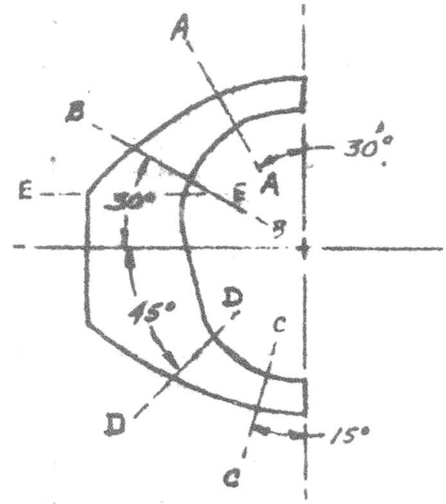
$$H_1 = H_2 = \frac{2A_1 q_{T_1} - 2A_2 q_{T_2}}{16.83}$$

$$H_1 = H_2 = \frac{(27.95)(253) - (42.17)(137)}{16.83} = 250.4\#$$

$$V_1 = V_2 = \frac{q_{T_1} h_1 + q_{T_2} h_2}{2}$$

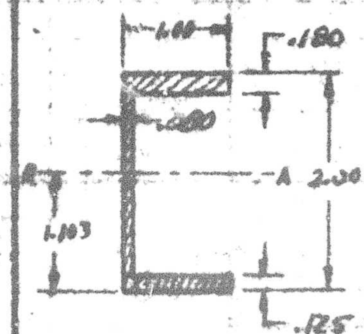
$$V_1 = V_2 = \frac{(27.95)(18.46) + (42.17)(15)}{2} = 55.5\#$$

RIB - STA 24.25



SECTIONS A-A THRU E-E AS SHOWN WILL BE INVESTIGATED AS TYPICAL SECTIONS FORE AND AFT IN THE RIB.

SECTION A-A



$$A = (1.00)(2.00) - (2.00 - .180 - .125)(1.00 - .05) = .44\ IN^2$$

$$N.A. = \frac{(2.00)(1.00) - (1.56)(.973)}{.44} = 1.103\ IN$$

$$I_{NA} = \frac{(1.00)(2.00)^3}{12} + (2.00)(.103)^2 - \left[\frac{(.92)(1.695)^3}{12} + (1.56)(.130)^2\right]$$

$$I_{NA} = .293\ IN^4$$

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

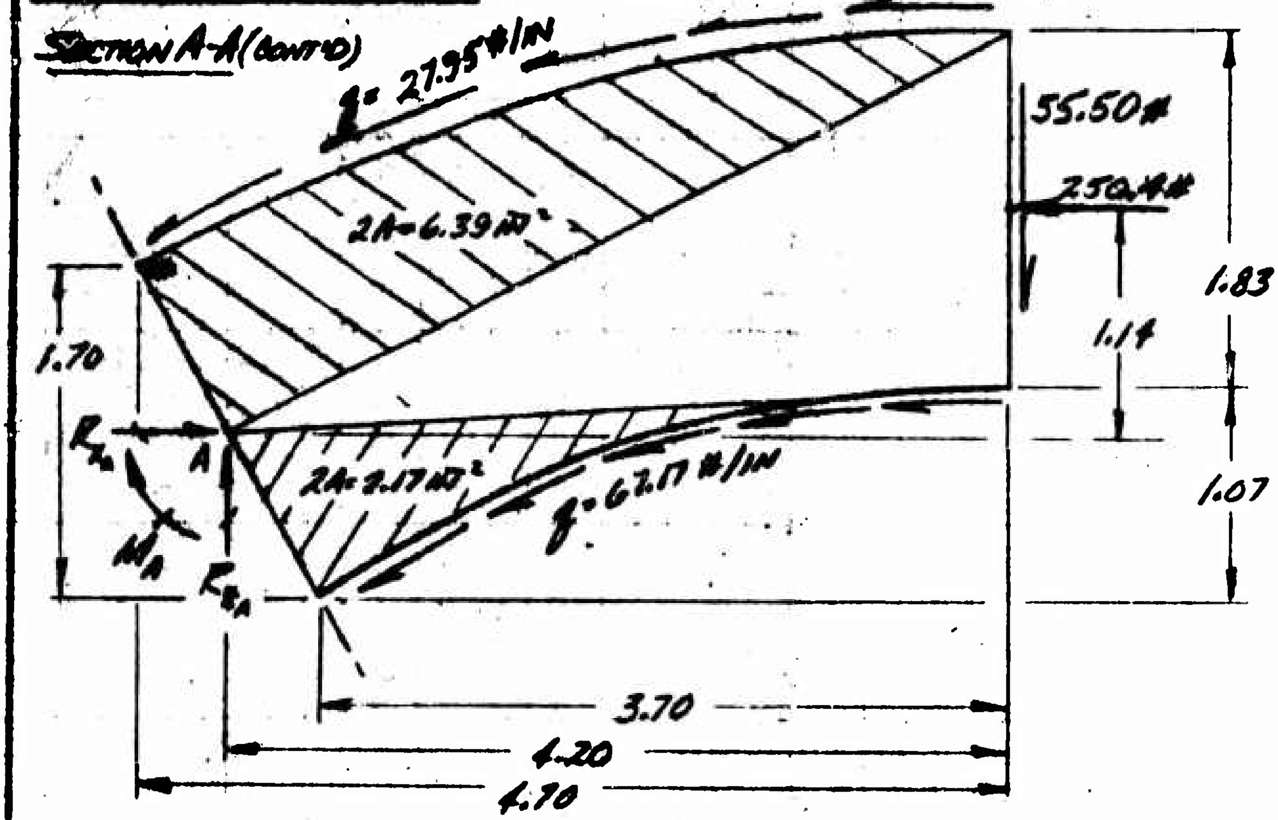
ANALYSIS: Hot Cycle Rotor MODEL: 285 REPORT NO. 285-13 PAGE 5.2.2.2.2

PREPARED BY: [illegible] CHECKED BY: [illegible]

ROTOR BLADE

INBOARD TORQUE BOX **UNHEATED FATIGUE COND**

SECTION A-A (CONT'D)



$$\sum M_A = 0 = (55.50)(4.2) + (67.17)(2.17) - (250.4)(1.14) - (27.95)(6.39) + M_A$$

$$\underline{M_A = -85.2 \text{ in\#}}$$

$$\sum X = 0 = R_{x_A} - 250.4 - (27.95)(4.9) - (67.17)(3.7)$$

$$\underline{R_{x_A} = 630.3\#}$$

$$\sum Z = 0 = R_{z_A} - 55.50 - (67.17)(1.07) - (27.95)(1.2)$$

$$\underline{R_{z_A} = 160.9\#}$$

$$f_b = \frac{Mz}{I} = \frac{(85.2)(1.103)}{.293} \qquad \underline{f_b = 321 \text{ PSI (COMP)}}$$

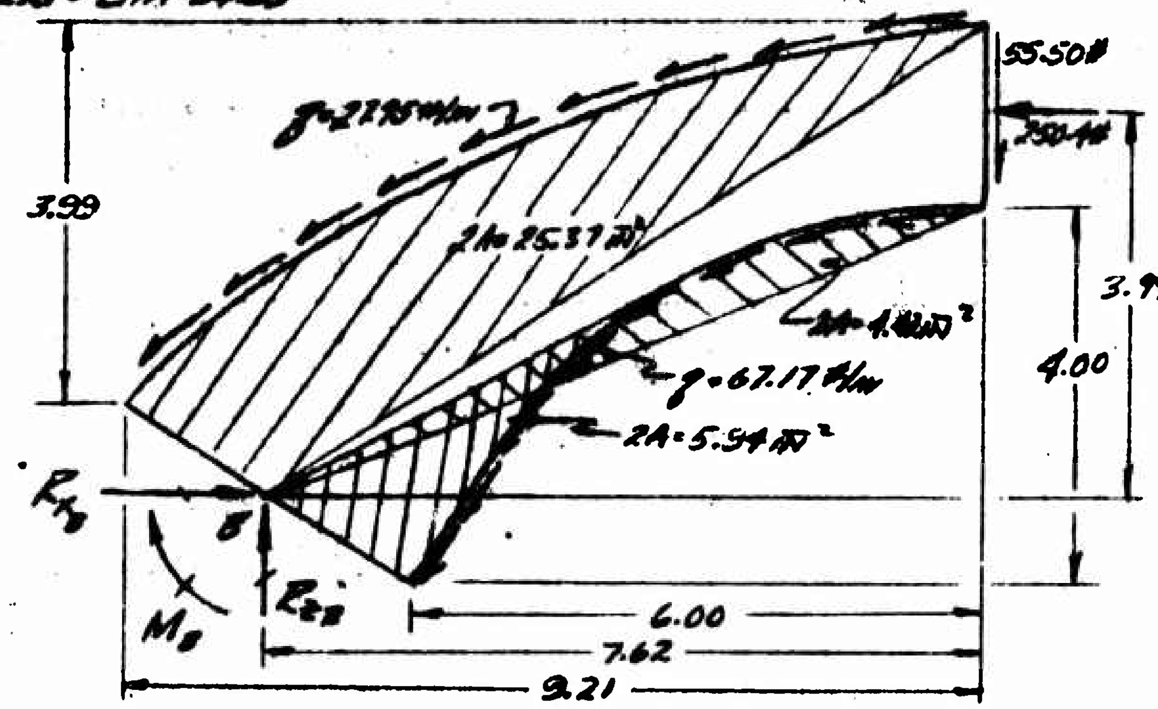
$$f_c = \frac{630.3 \cos 30° + 160.9 \sin 30°}{.390} \qquad \underline{f_c = 1422 \text{ PSI}}$$

$$f_s = \frac{630 \sin 30° - 160.9 \cos 30°}{(2.00)(.080)} \qquad \underline{f_s = 1100 \text{ PSI}}$$

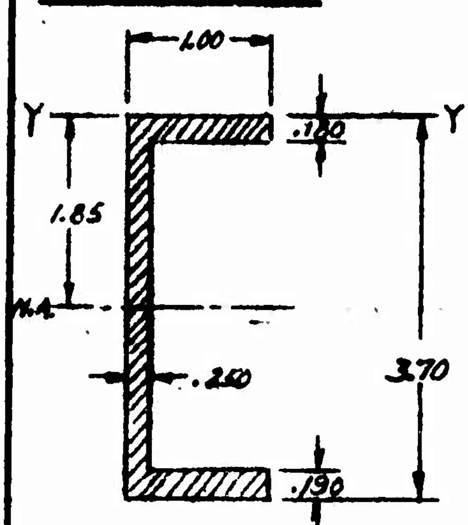
ROTOR BLADE

INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

RIB - STA 24.35



SECTION B-B



$$A = (1.00)(3.70) - (3.70 - .18 - .19)(.75) = 1.20\ \overline{IN}^2$$

$$I_{NA} = \frac{(1.00)(3.70)^3}{12} - \frac{(.75)(3.33)^3}{12}$$

$$= 1.913\ \overline{IN}^4$$

UNBONDED TORSIONAL BOX — SECTION B-B (CONT'D)

UNBONDED FATIGUE COND — RIB STA 24.25

$\Sigma M_B = 0 = M_B - (27.95)(25.37) + 55.50(2.62) - (250.4)(3.99) + (67.17)(1.92)$

$M_B = 1187 \text{ in\#}$

$\Sigma X = 0 = R_{X_B} - 250.4 - (27.95)(9.21) - (67.17)(6.0)$

$R_{X_B} = 910.8\#$

$\Sigma Z = 0 = R_{Z_B} - 55.50 - 27.95(3.99) - 67.17(4.0)$

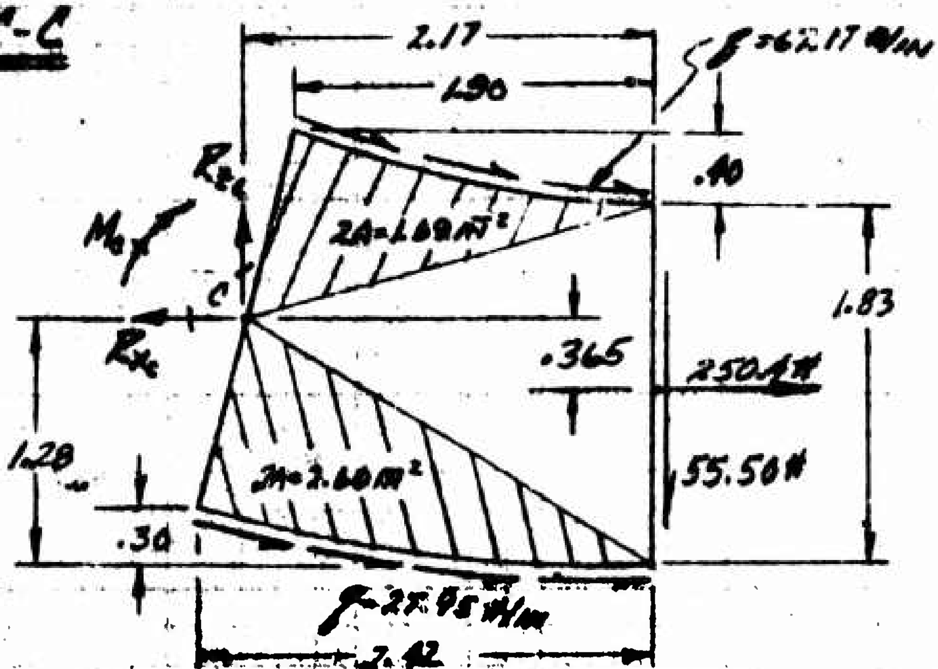
$R_{Z_B} = 435.7\#$

$f_b = \dfrac{Mc}{I} = \dfrac{(1187)(1.86)}{1.413}$ $\qquad f_b = 1954 \text{ PSI (COMP)}$

$f_c = \dfrac{910.8 \sin 30° + 435.7 \cos 30°}{1.20}$ $\qquad f_c = 695 \text{ PSI}$

$f_s = \dfrac{910.8 \cos 30° - 435.7 \sin 30°}{(3.70)(.25)}$ $\qquad f_s = 617 \text{ PSI}$

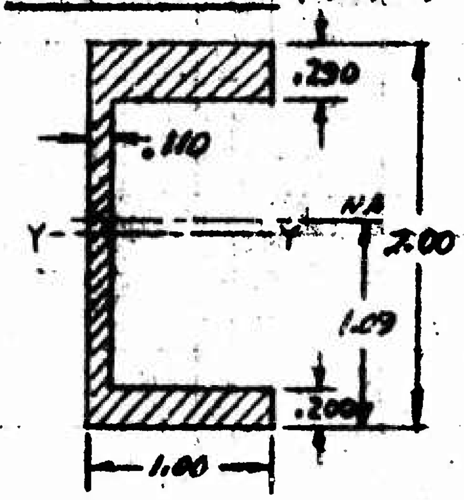
SECTION C-C



INBOARD TORQUE BOX WEIGHTED FATIGUE COND.

BL-STA 14.25

SECTION C-C (CONT'D)



$A = (2.00)(1.00) - (2.00 - .230 - .200)(1.00 - .110)$

$A = .656\ IN^2$ ✓

$N.A. = \frac{(2.00)(1.00) - (1.321)(.955)}{.656} = 1.09\ IN$

$I_{YY} = \frac{(1.00)(2.00)^3}{12} - \frac{(.89)(.71)^3}{3} - \frac{(.89)(.80)^3}{3}$

$I_{YY} = .4085\ IN^4$

$I_{NA} = I_{YY} - A\bar{z}^2 = .4085 - (.656)(.09)^2 = .4032\ IN^4$

$\overrightarrow{\Sigma X} = 0 = 250.4 + 27.95(2.42) + 67.17(1.90) - R_{X_c}$

$R_{X_c} = 445.6\ \#$ ✓

$\uparrow \Sigma Z = 0 = -55.50 - 67.17(.40) - 27.95(.30) + R_{Z_c}$

$R_{Z_c} = 90.76\ \#$ ✓

$\Sigma M_c = 0 = M_c + (67.17)(1.69) + (55.5)(1.17) - (27.95)(2.60) - (250.4)(.365)$

$M_c = -69.89\ IN\#$

$f_s = \frac{90.76 \cos 15° - 445.6 \sin 15°}{(2.00)(.110)}$ $f_s = 125.5\ PSI$

$f_t = \frac{90.76 \sin 15° + 445.6 \cos 15°}{.656}$ $f_t = 691.9\ PSI$

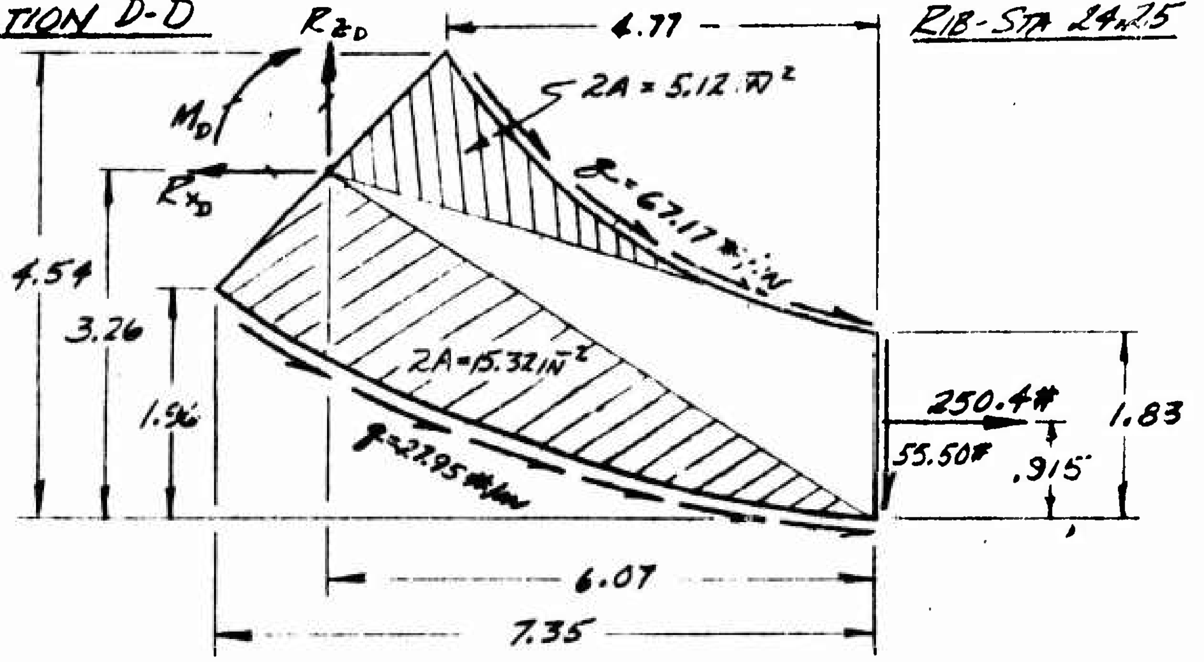
$f_b = \frac{Mz}{I} = \frac{(69.89)(1.09)}{.4032}$ $f_b = 188.7\ PSI\ (COMP)$

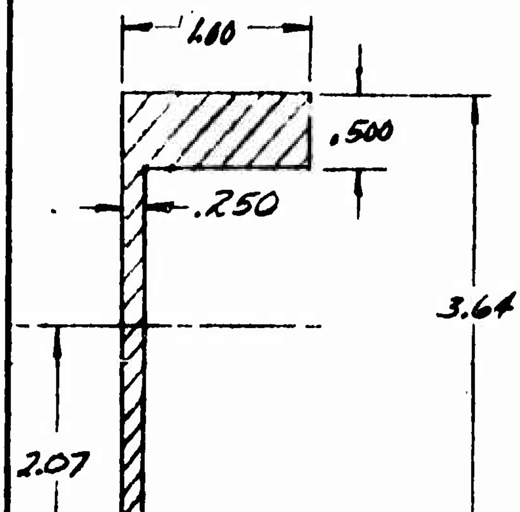
Rotor Blade

INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

SECTION D-D

RIB-STA 24.25





$$A = (3.64)(1.00) - (3.64 - .50 - .18)(.75) = 1.42\ IN^2$$

$$N.A. = \frac{(3.64)(1.82) - (2.22)(1.66)}{1.42} = 2.07\ IN$$

$$I_{NA} = \frac{(1.00)(2.07)^3}{3} - \frac{(.75)(1.89)^3}{3} + \frac{(1.00)(1.57)^3}{3} - \frac{(.75)(1.07)^3}{3} = 2.253\ IN^4$$

INBOARD TORQUE BOX WEIGHTED FATIGUE COND.

SECTION D-D (CONT'D) RIB - STA 24.25

$$\Sigma Z = 0 = R_{Z_D} - 56.50 - 67.17(4.54 - 1.83) - 27.95(1.96)$$

$$R_{Z_D} = 292.3\#$$

$$\Sigma X = 0 = 250.4 + 27.95(7.35) + 67.17(4.77) - R_{X_D}$$

$$R_{X_D} = 716.2\#$$

$$\Sigma M_D = 0 = M_D + 67.17(5.12) - 27.95(15.32) + 55.5(6.07) - 205.4(2.345)$$

$$M_D = 229.1''\#$$

$$f_s = \frac{776.2 \sin 45^\circ - 292.3 \cos 45^\circ}{(3.64)(.250)} \qquad f_s = 376 \text{ PSI}$$

$$f_t = \frac{776.2 \cos 45^\circ + 292.3 \sin 45^\circ}{1.42} \qquad f_t = 533 \text{ PSI}$$

$$f_b = \frac{Mz}{I} = \frac{(229.1)(2.104)}{} \qquad f_b = 214 \text{ PSI (TENSION)}$$

THE PORTION OF THE BEAM BETWEEN SECTIONS B-B AND D-D IS CONSIDERED AS A SLOTTED BEAM, THE SECTIONS FORE AND AFT OF THE FWD STRAP CUTOUT BEING ANALYZED SEPARATELY. THE DISTRIBUTION OF THE LOADS FROM THE REMAINDER OF THE RIB IS MADE ON THE BASIS OF INDIVIDUAL STIFFNESS AND THE GEOMETRY OF THE RIB. ON THIS ASSUMPTIO THE SECTION AFT OF THE CUTOUT WILL RESIST THE ENTIRE HORIZONTAL SHEAR LOAD ON THE BEAM.

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

5.2.9.2.8

ANALYSIS HOT CYCLE ROTOR MODEL 285 REPORT NO. 285-13 PAGE —

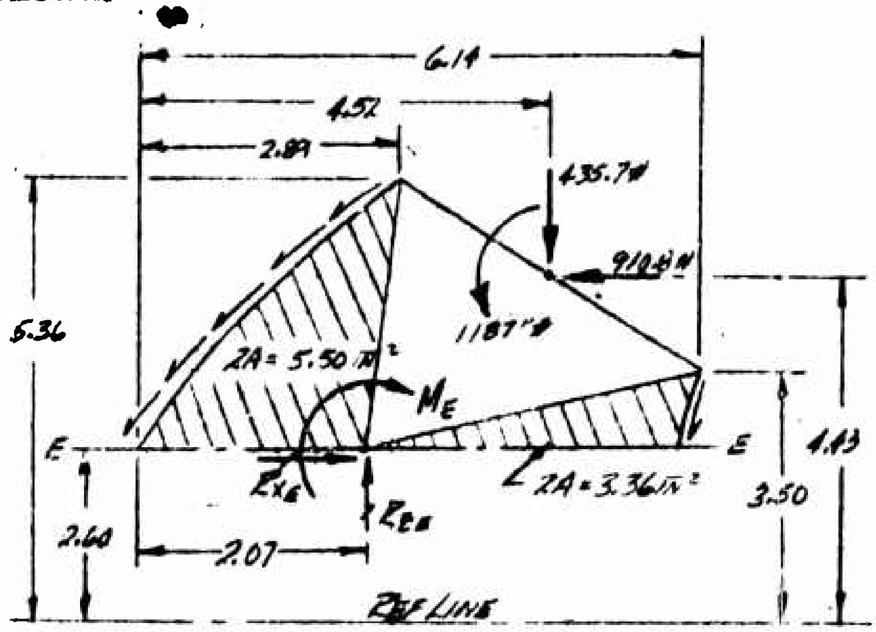
PREPARED BY L.L. [illegible] 3-29-60

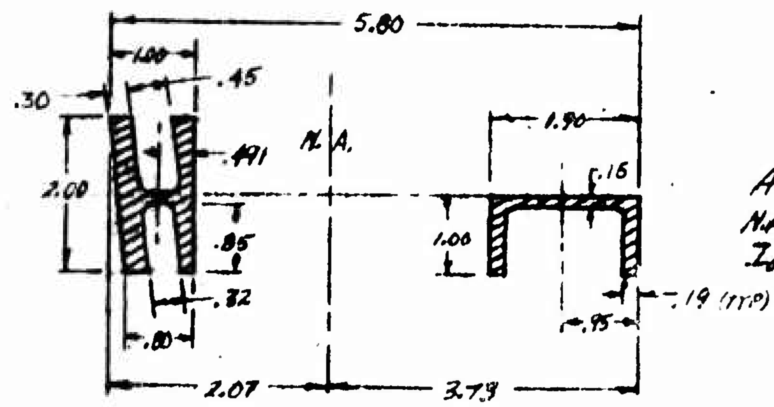
CHECKED BY

ROTOR BLADE

INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

RIB-STA 24.75





A = 1.08 IN²
N.A. = .491
I_o

A = .608 IN²
N.A. = .95 IN
I_o = .323 IN⁴

$$N.A. = \frac{(1.08)(5.29) + (.608)(.95)}{1.08 + .608} = 3.727 \text{ IN}$$

$$\Sigma M_E = 0 = M_E - 1187 - 27.95(5.50) - 910.8(1.83) + 67.17(3.36) + (435.7)(2.45)$$

$M_E = 1714$ "#

$$\Sigma Z = 0 = R_{Z_E} - 435.7 - 27.95(2.76) - 67.17(.90)$$

$R_{Z_E} = 573.3$#

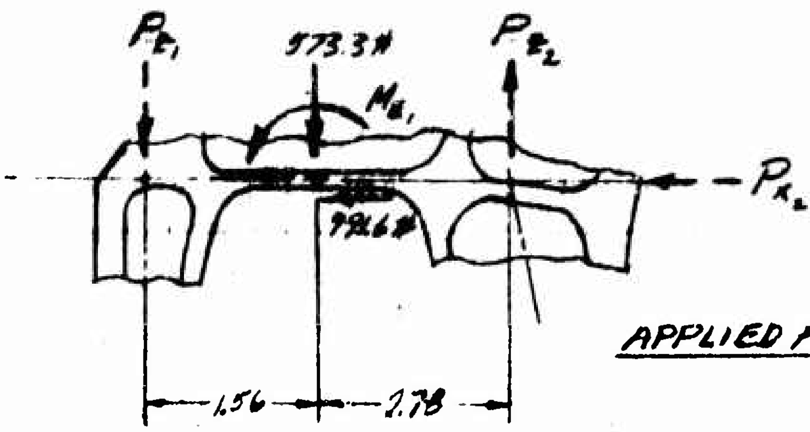
$$\Sigma X = 0 = R_{X_E} - 910.8 - 27.95(2.89)$$

$R_{X_E} = 991.6$#

9704

INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

APPLIED LOADS TO BEAM PORTIONS — RIB - STA 24.25



APPLIED FORCES

$M_{E_1} = M_E + 2000$ IN-# (MOMENT DUE TO ARBITRARY SHEAR OF 500 # IN AFT PORTION OF BEAM)

$M_{E_1} = 1714 + 2000 = 3714$ IN-#

$$P_{Z_1} = \frac{573.3(2.78) + 3714}{1.56 + 2.78} = 1223\#$$

$$P_{Z_2} = \frac{3714 - 573.3(1.56)}{4.34} = 650\#$$

$$P_{X_2} = 991.6\#$$

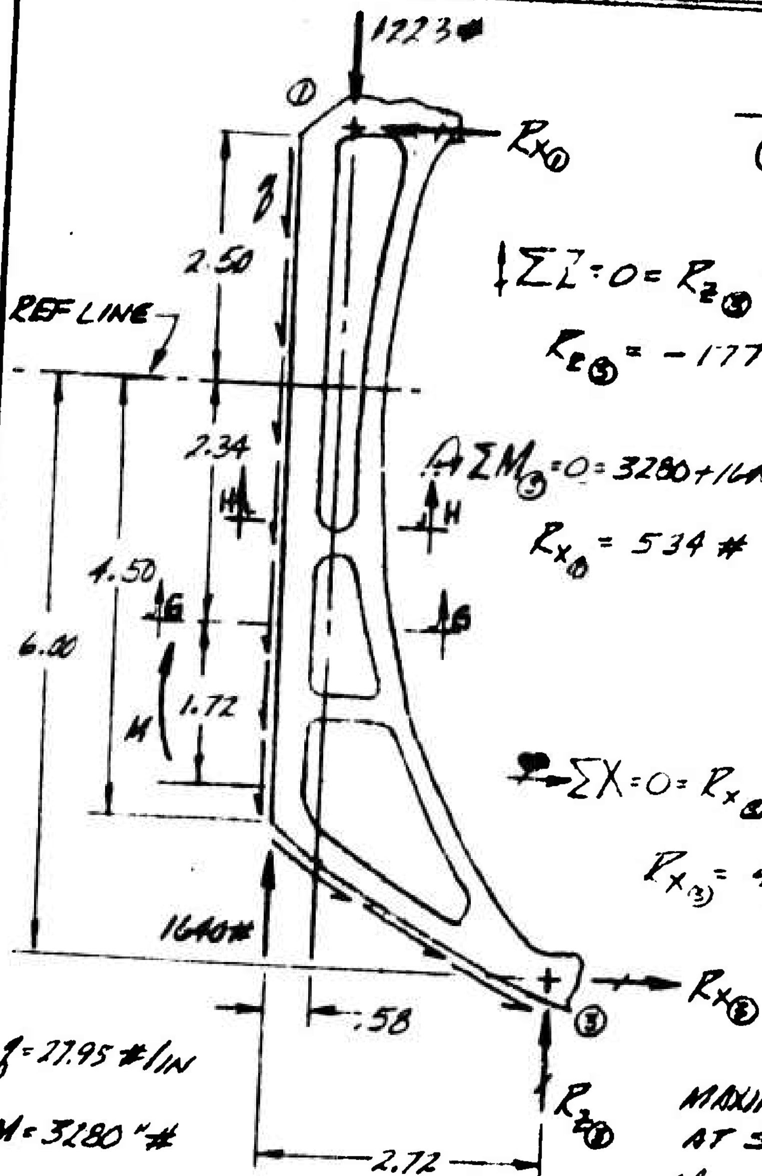
SECTION FWD OF FWD STRAP CUTOUT

THIS SECTION WILL BE TREATED AS A BEAM WITH PIN END FIXITY ON BOTH ENDS.

INBOARD TORQUE BOX

WEIGHTED FATIGUE COND

SECTION FWD OF FWD STRAP CUTOUT (CONT'D)



RIB - STA 24.25

(REF DWG 285-0189)

MAT'L - 4130 STL, H.T. 95 KSI

$\Sigma Z = 0 = R_{z_③} + 1640 - 1223 - 27.95(8.60)$

$R_{z_③} = -177\#$

$\Sigma M_③ = 0 = 3280 + 1640(2.72) - 1223(2.14) - 27.95(19.04) - 8.6 R_{x_①}$

$R_{x_①} = 534\#$

$\Sigma X = 0 = R_{x_③} + 27.95(2.72) - 534$

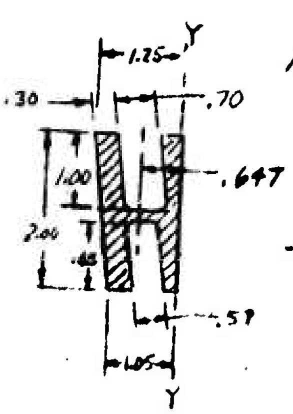
$R_{x_③} = 488\#$

$f = 27.95\ \#/IN$

$M = 3280\ ''\#$

MAXIMUM MOMENT OCCURS AT SECTION G-G

$M_{G-G} = 534(4.84) = 2585\ ''\#$



SECTION G-G

$$N.A. = \frac{(1.05)(2.0)(.525) + \frac{(.20)(2.0)}{2}(1.12) - (1.00)(.70)(.54) - (.85)(.57)(.47)}{(1.05)(2.0) + \frac{(.20)(2.0)}{2} - (1.00)(.70) - (.85)(.57)}$$

$$= \frac{.721}{1.115} = .647\ IN$$

$$I_{YY} = \frac{(2.00)(1.05)^3}{3} + \frac{(2.00)(.20)^3}{36} + (.20)(1.12)^2 - \frac{(1.00)(.70)^3}{12} - (1.00)(.70)(.54)^2 - \frac{(.85)(.57)^3}{12} - (.85)(.57)(.47)^2$$

$$= .700\ IN^4$$

INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

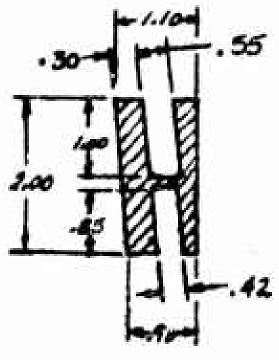
SECTION FWD OF FWD STRAP CUTOUT (CONT'D)

RIB - STA 24.25

SECTION G-G (CONT'D)

$$I_{NA} = I_{YY} - A\bar{x}^2 = .700 - (1.115)(.647)^2 = .234$$

$$f_b = \frac{(2585)(.647)}{.234} = 7150 \text{ PSI (UNIT)}$$



MINIMUM SECTION OCCURS AT THE REF. LINE. HOWEVER, THERE IS VERY LITTLE BUILD-UP BETWEEN THE REF LINE AND SECTION H-H WHERE A LARGER MOMENT IS APPARENT.

$$M_{H-H} = 4.00(534) = 2136 \text{ "\#}$$

SECTION H-H

$$N.A. = \frac{(.90)(2.00)(.45) + \frac{(.20)(2.00)}{2}(.97) - (1.00)(.55)(.47) - (.85)(.42)(.40)}{(.90)(2.00) + \frac{(.20)(2.00)}{2} - (1.00)(.55) - (.85)(.42)} = \frac{.601}{1.093} = .550 \text{ IN}$$

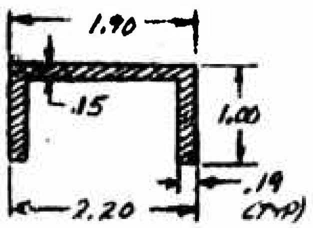
$$I_{YY} = \frac{(2.00)(.90)^3}{3} + \frac{(2.00)(.20)^3}{36} + (.200)(.97)^2 - \frac{(1.00)(.55)^3}{12} - 1.00(.55)(.47)^2 - \frac{.85(.42)^3}{12} - .85(.42)(.40)^2 = .477 \text{ IN}^4$$

$$I_{NA} = .477 - (1.093)(.550)^2 = .146 \text{ IN}^4$$

$$f_b = \frac{2136(.55)}{.146} = 8050 \text{ PSI (UNIT)}$$

INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

RIB - STA 24.25 — SECTION AFT OF FWD STRAP CUTOUT (SECTION J-J)



$A = .608\ IN^2$

$N.A. = .95\ IN$

$$I_{NA} = \frac{(1.00)(2.2)^3 - (.85)(1.82)^3}{12} = .461\ IN^4$$

MAXIMUM MOMENT OCCURS AT UPPER END OF BEAM

SHEAR IN BEAM = 991.6 - 534 = 458#

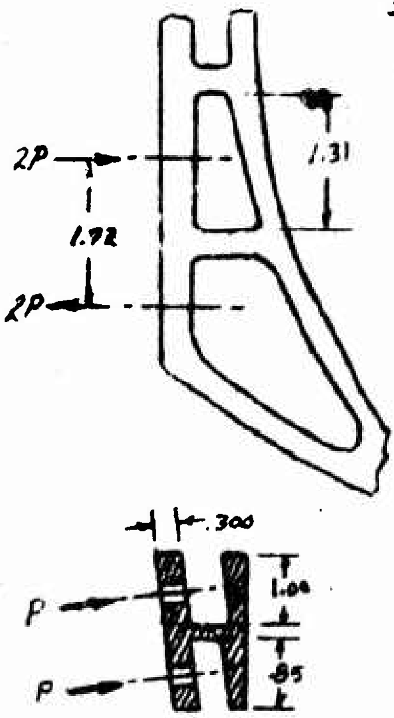
BEAM LENGTH = 8.0 IN

ASSUMING SHEAR LOAD APPLIED AT BEAM CENTER MOMENT AT THE ENDS IS AS FOLLOWS:

$$M = 458 \times 4 = 1832\ ''\#$$

$$f_b = \frac{1832\,(1.1)}{.461} = 4370\ PSI\ (UNIT)$$

PITCH ARM ATTACHMENT



$COUPLE = M = 3280\ ''\#$

$$2P = \frac{3280}{1.72} = 1907\#$$

$P = 954\#$

ASSUMING A BEAM WITH ENDS FIXED

$$M_{MAX} = \frac{1}{8} P \cdot l \quad (\text{REF 2, TABLE III CASE 31})$$

$$M_{MAX} = \frac{1}{8}(954)(1.31) = 156''\#$$

$$I_{MIN} = \frac{(.30)(.85)^3}{12} = .015\ IN^4$$

$$f_b = \frac{(156)(.43)}{.015} = 4472\ PSI\ (UNIT)$$

ANALYSIS Hot Cycle Rotor MODEL 285 REPORT NO. 285-13

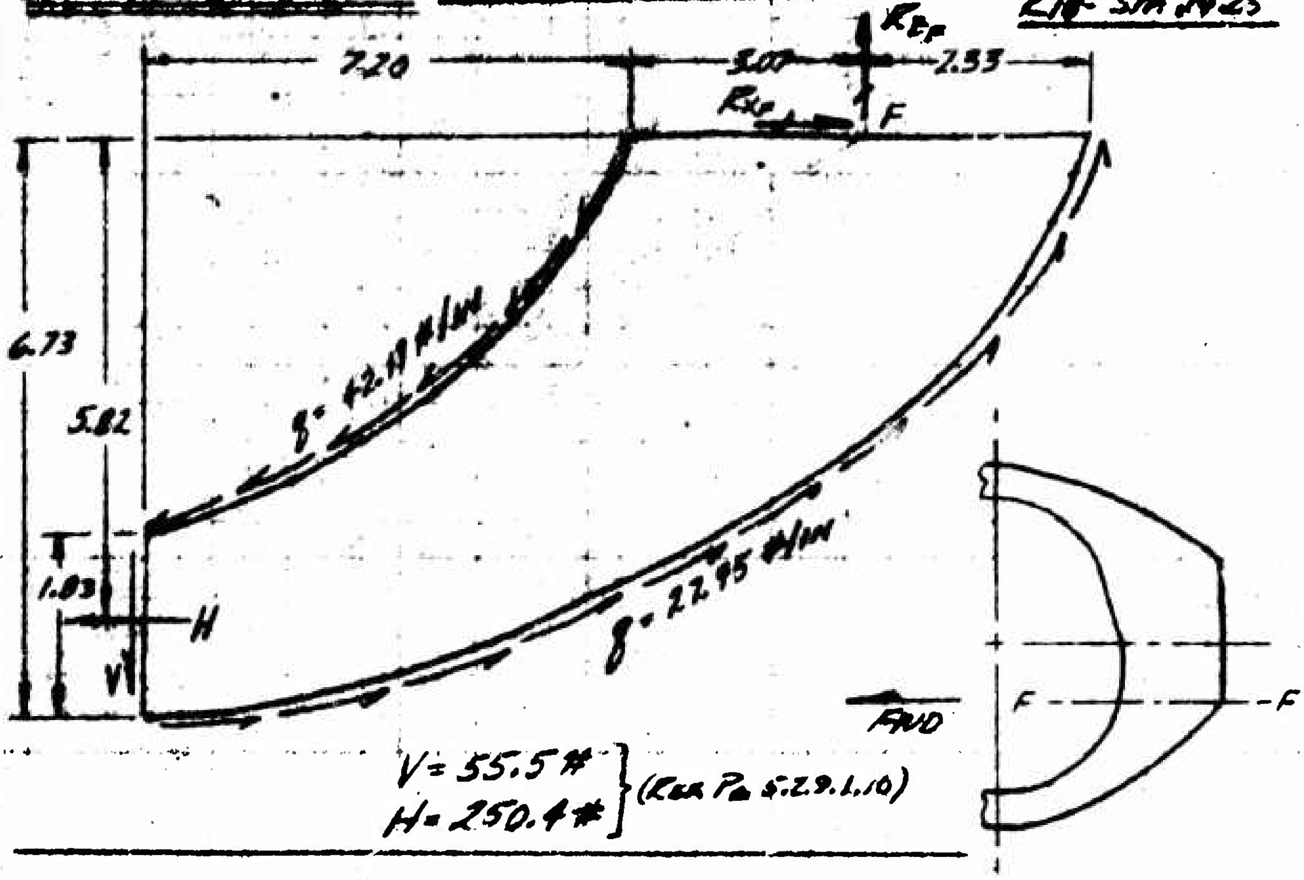
PREPARED BY ... 1-29-6...

CHECKED BY

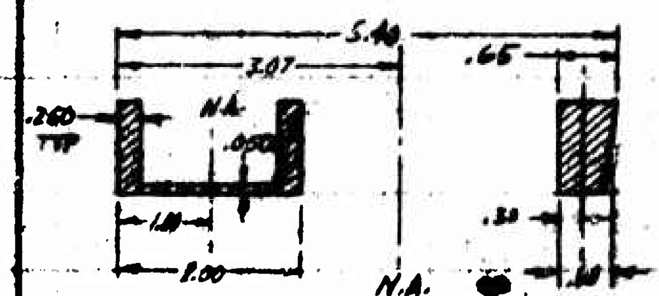
ROTOR BLADE

INBOARD TORQUE BOX UNBALANCED FATIGUE COND

Z18 - STA 14.25



$V = 55.5\#$
$H = 250.4\#$ } (REF PG 5.2.9.1.10)



$A = (2.40)(1.00) - (1.50)(.95) + (.60)(1.00) = 1.175\ IN^2$

$N.A. = \dfrac{(.575)(1.00) + (.60)(5.05)}{1.175} = 3.07\ IN$

$\Sigma M_F = 0 = M_F + 250.4(5.82) - 27.95(40.97) + 42.17(1.19) - 55.5(10.27)$

$\underline{M_F = 305\ IN\text{-}\#}$

$\Sigma Z = 0 = R_{Z_F} + 27.95(6.73) - 42.17(4.90) - 55.5$

$\underline{R_{Z_F} = 75\#}$

$\Sigma X = 0 = R_{X_F} - 251 - 42.17(7.20) + 27.95(12.08)$

$\underline{R_{X_F} = 217\#}$

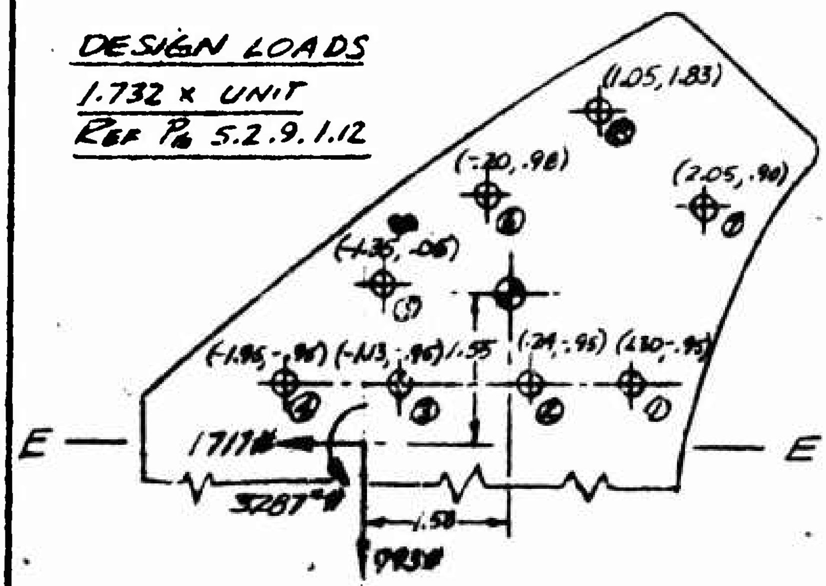
INBOARD TORQUE BOX WEIGHTED FATIGUE COND

RIB - STA 24.25

ATTACHMENT OF RIB SEGMENT (REF DWG 285-0189)

UPPER PATTERN - .312 DIA BOLTS

DESIGN LOADS
1.732 x UNIT
REF PG 5.2.9.1.12



BOLT	$\bar{X}^2$	$\bar{Y}^2$
1	1.690	.903
2	.058	.902
3	1.277	.903
4	3.893	.902
5	1.822	—
6	.040	.960
7	4.202	.810
8	1.103	3.349
Σ	13.995	8.729

$$I_P = \Sigma_N (\bar{X}^2 + \bar{Y}^2) = 13.995 + 8.729 = 22.72$$

DIRECT LOADS TO BOLTS -

$$P_{X/BOLT} = \frac{1717}{8} = 215\#\ ; \quad P_{Y/BOLT} = \frac{993}{8} = 124\#$$

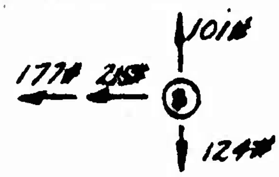
$$\Sigma M_{⑧} = -3287 - 993(1.58) + 1717(1.55) = -2194\ "\#$$

$$P_{X_M} = \frac{M\bar{Y}}{I_P}\ ; \quad P_{Y_M} = \frac{M\bar{X}}{I_P}$$

BOLT No. 8, BEING THE EXTREME OUTSIDE BOLT IN THE PATTERN, WILL RECIEVE THE LARGEST LOADING

$$P_{X_M} = \frac{2194(1.83)}{22.72} = 177\#$$

$$P_{Y_M} = \frac{2194(1.05)}{22.72} = 101\#$$



$$P_{⑧} = \sqrt{392^2 + 23^2} \cong 393\#$$

$$f_{br} = \frac{393}{(.3125)(.250)} = 5038\ PSI \qquad M.S. = \frac{7650}{5038} - 1 = \underline{\underline{.52}}$$

F_B = 7650 PSI (REF PG 5.2.9.4.0)

9704

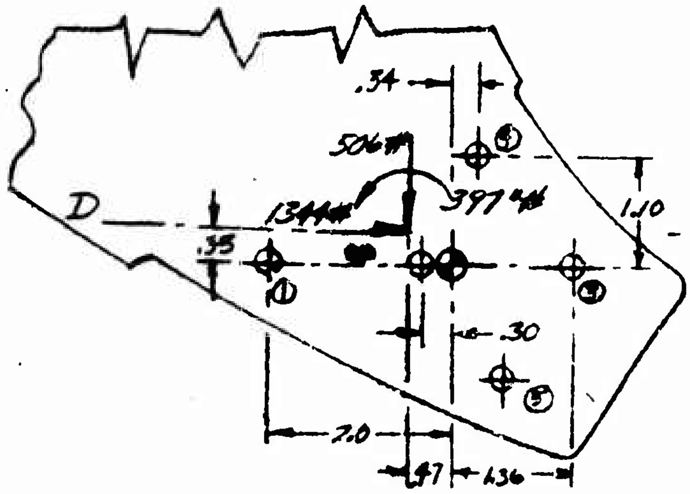
INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

RIB - STA 24.25

ATTACHMENT OF RIB SEGMENT

LOWER PATTERN .312 DIA BOLTS

DESIGN LOADS
1.732 x UNIT
REF PG 5.2.9.2.11



BOLT	$\bar{X}^2$	$\bar{Y}^2$
1	4.00	0
2	.09	0
3	1.85	0
4	.12	1.21
5	.36	1.30
Σ	6.42	2.51

$I_p = \Sigma_N(\bar{X}^2+\bar{Y}^2) = 6.42+2.51 = 8.93$

$\Delta M_{②} = -397-506(.47)+1344(.35) = 165$ "#

DIRECT LOADS TO BOLTS -

$P_{X_{BOLT}} = \frac{1344}{5} = \overrightarrow{269\#}$

$P_{Y_{BOLT}} = \frac{397}{5} = 79\#\downarrow$

BOLT No 1 BEING THE EXTREME OUTSIDE BOLT IN PATTERN -

$P_{X_M} = \frac{165(0)}{8.93} = 0$

$P_{Y_M} = \frac{165(2.0)}{8.93} = 37.2\#$

① 269# → ; 79# ↓ ; 37# ↓

$P_{①} = \sqrt{\overline{269}^2 + \overline{116}^2} = 293\#$

$f_{br} = \frac{293}{(.3125)(.25)} = 3760\ PSI$

$M.S. = \frac{7650}{3760} - 1 = \underline{\underline{1.04}}$

$F_a = 7650\ PSI$ (REF PG 5.2.9.4.0)

HUGHES TOOL COMPANY-AIRCRAFT DIVISION 5.2.9.2.16

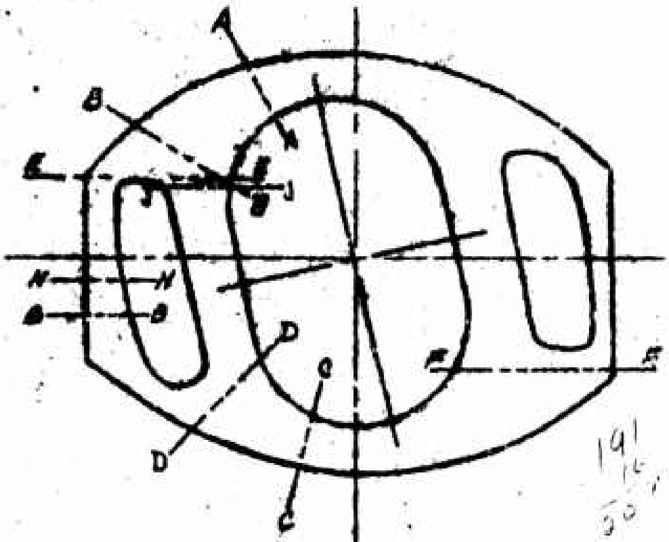
ANALYSIS Hot Cycle Rotor MODEL 285 REPORT NO. 285-13 PAGE

PREPARED BY Z.L. [illegible]

CHECKED BY

ROTOR BLADE

LOADS AND STRESSES SUMMARY - WEIGHTED FATIGUE COND.



R18 - STA 24.25

DWG 285-0190
285-0189
285-0134

19|
16
50

SECT CUT	g_{OT} (#/in) UNIT / ACTUAL	g_{IT} (#/in) UNIT / ACTUAL	M (in-#) UNIT / ACTUAL	K_x (#) UNIT / ACTUAL	K_z (#) UNIT / ACTUAL	f_t (PSI) UNIT / ACTUAL	f_b or f_a (PSI) UNIT / ACTUAL	f_s (PSI) UNIT / ACTUAL	M.S.	REMARKS
A-A	27.95	67.17	85.2	630.3	160.9	321	1422	1100	–	
	48.4	116.3	147.6	1092	287.7	556	2462	1905	2.64	
B-B	27.95	67.17	1187	910.2	435.7	1154	695	617	–	
	48.4	116.3	2056	1576	754.6	2000	1203	1070	2.44	
C-C	27.95	67.17	69.89	445.6	90.76	189	692	126	–	
	48.4	116.3	1210	774.8	157.2	327	1198	217	–	
D-D	27.95	67.17	229.1	776.2	292.3	214	533	376	–	
	48.4	116.3	396.8	1344	506.3	370	923	650	–	
E-E	27.95	67.17	1898	991.6	573.3	–	–	–	–	
	48.4	116.3	3287	1717	992.9	–	–	–	–	
F-F	27.95	42.17	305	217	75	–	–	–	–	
	48.4	73.0	528	376	130	–	–	–	–	
G-G	–	–	2585	534	177	7150	159	480	–	
	–	–	4477	925	307	12380	275	830	.94	STEEL
H-H	–	–	2136	534	177	8050	162	490	–	
	–	–	3700	925	307	13940	280	850	.72	STEEL
J-J	–	–	1832	458	650	4370	1070	753	–	
	–	–	3173	793	1126	7570	1853	1304	–	STEEL

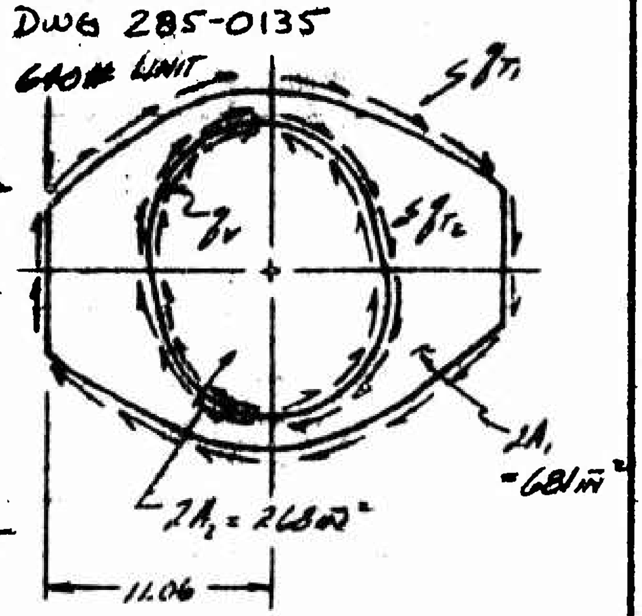
ACTUAL VALUE = 1.732 × UNIT VALUE

g_{OT} = OUTER TUBE [illegible]

g_{IT} = INNER TUBE [illegible] FLOW

INBOARD TORQUE BOX WEIGHTED FATIGUE COND

5.2.9.3 RIB - STA 33.25 DWG 285-0135



$T_{TOTAL} = 640(11.06) = 7080$ IN-# UNIT

$T_1 = \frac{T_{TOT}\,J_1}{J_{TOT}} = \frac{(7080)(488)}{571} = 6050$ "# UNIT

$T_2 = \frac{T_{TOT}\,J_2}{J_{TOT}} = \frac{(7080)(83)}{571} = 1030$ "# UNIT

ASSUMING A CONSTANT q_V RESISTING 640# -

$q_V = \frac{V}{2h} = \frac{640}{2(15)} = 21.33$ #/IN UNIT

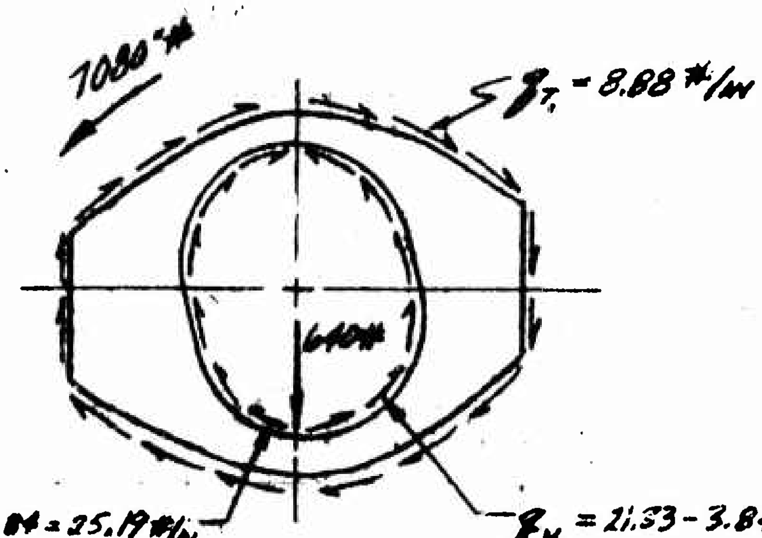
$q_{T_1} = \frac{T_1}{2A_1} = \frac{6050}{681} = 8.88$ #/IN UNIT

$q_{T_2} = \frac{T_2}{2A_2} = \frac{1030}{268} = 3.84$ #/IN UNIT

$q_V = 21.33$ #/IN UNIT

$q_{T_1} = 8.88$ #/IN UNIT

$q_{T_2} = 3.84$ #/IN UNIT



$q_{V_1} = 21.33 - 3.84 = 25.19$ #/IN

$q_{V_2} = 21.33 - 3.84 = 17.49$ #/IN

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE ROTOR — MODEL 285 — REPORT NO. 285-13 — PAGE 5.2.9.3.1

PREPARED BY: L.L. ERLE 5-18-60

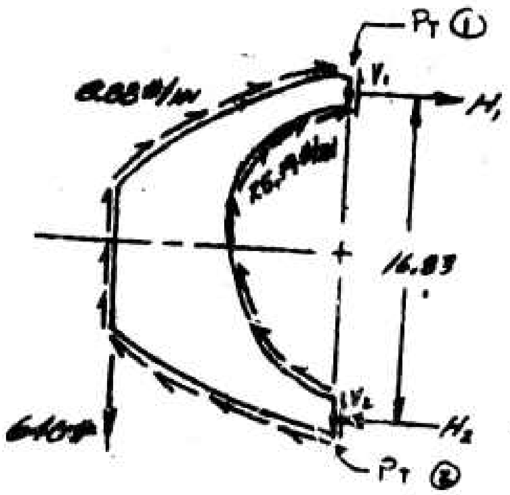
CHECKED BY:

ROTOR BLADE

INBOARD TORQUE BOX

WEIGHTED FATIGUE COND

RIB STA 33.25



AGAIN ASSUMING A POINT OF INFLECTION AT POINT ① —

THE AFT PORTION SHEAR FLOWS ARE REPRESENTED BY THE HORIZONTAL AND VERTICAL LOADS AS SHOWN.

$$H_1 = H_2 = \frac{2A_1 q_{T_1} - 2A_2 q_{V_2}}{16.83}$$

$$= \frac{(340.5)(8.88) - (30)(17.49)}{16.83}$$

$$H_1 = H_2 = 40.4\# \text{ UNIT}$$

$$V_1 = V_2 = \frac{q_{T_1} h_1 + q_{V_2} h_2}{2}$$

$$= \frac{(8.88)(18.66) + (17.49)(13)}{2}$$

$$V_1 = V_2 = 48.4\# \text{ UNIT}$$

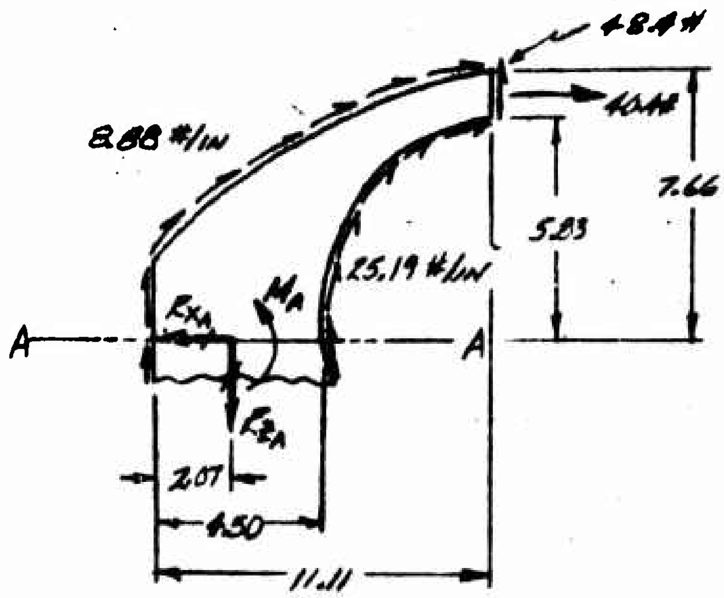
9704

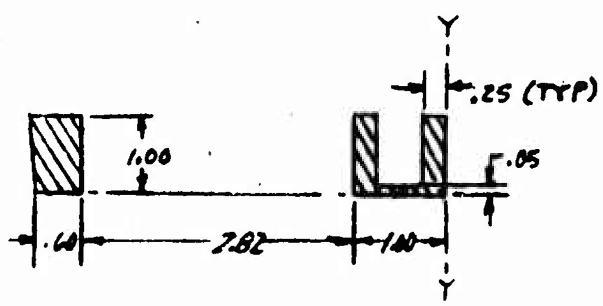
INBOARD TORQUE BOX

WEIGHTED FATIGUE COND

RIB - STA 53.25

SINCE THE LOADING IS CONSIDERABLY LOWER FOR THIS RIB THAN IN THE STA 24.25 RIB, ONLY THE CRITICAL PORTION OF THE RIB WILL BE INVESTIGATED.





$$N.A. = \frac{[(1.0)(1.0)-(.95)(.50)](.50)+[(.60)(1.0)](4.12)}{(1.0)(1.0)-(.95)(.50)+(.60)(1.0)}$$

$= 2.43$ IN

$$\sum X = 0 = (8.88)(11.11)+(25.19)(6.61)+(40.4)-R_{X_A}$$

$R_{X_A} = 305.6\#$ UNIT

$$\sum Z = 0 = (8.88)(7.66)+(25.19)(5.83)+48.4-R_{Z_A}$$

$R_{Z_A} = 263.3\#$ UNIT

$$\sum M = 0 = (8.88)(50.6)+(25.19)(14.4-7.2)+(40.4)(6.61)-(48.4)(9.04)-M_A$$

$M_A = 459.9$ "# UNIT

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE ROTOR — MODEL: 285 — REPORT NO. 285-13 — PAGE: 5.2.9.3.3

PREPARED BY: E.L. BODE 5-19-60

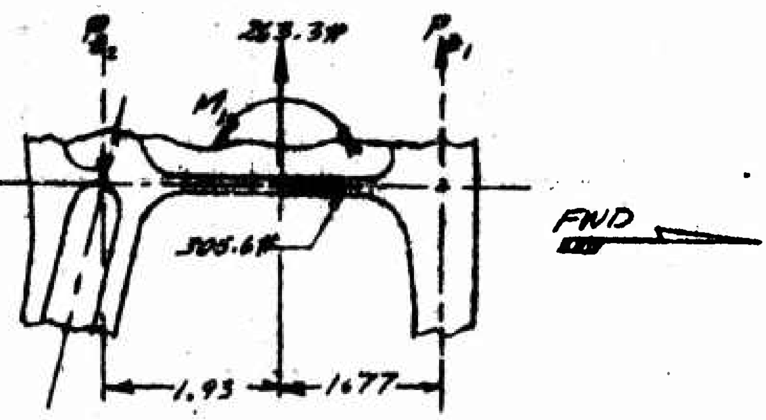
CHECKED BY:

ROTOR BLADE

INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

RIB-STA 35.25

APPLIED LOADS TO BEAM PORTIONS



$M_1 = M_A + 3.5(200)$ (200# ARBITRARY SHEAR IN AFT PORTION OF BEAM)

$M_1 = 460 + 700 = 1160$ "# UNIT

$P_{R_1} = \dfrac{(263.3)(1.93)+1160}{3.70} = 451$ # UNIT

$P_{R_2} = \dfrac{1160-(263.3)(1.77)}{3.70} = 188$ # UNIT

THE FWD PORTION OF THE BEAM IS NOW ISOLATED AND TREATED AS AS A SEPARATE BEAM WITHIN A BEAM WITH BOTH ENDS FIXED. THE LOCALLY APPLIED LOAD OF 640# IS POSITIONED AS ACTING ALONG THE APPROXIMATE NEUTRAL AXIS OF THE BEAM SO AS TO PRODUCE NO MOMENT. THIS WILL BE ACCOMPLISHED BY SO DESIGNING THE FITTING SO AS TO APPLY AN EQUAL AND OPPOSITE MOMENT TO THAT PRODUCED IN THE RIB. THIS MOMENT IS SHOWN BELOW.

$M_{UNIT} = 640(.30) = 192$ "#

$M_{ACTUAL} = 1300(.30) = 390$ "# LIM

WEIGHTED FATIGUE CONDITION

0704

MODIFIED TORQUE BOX

WEIGHTED FATIGUE COND

RIB - STA 53.25

CONSIDER THE SHEAR FLOW AS PRODUCING A COUPLE APPLIED AT THE CENTRE OF THE BEAM

$M_0 = (8.9)(6.85)(.30) = 18.25$ "# UNIT

FROM REF 2, CASE B, TABLE III CASE 37 -

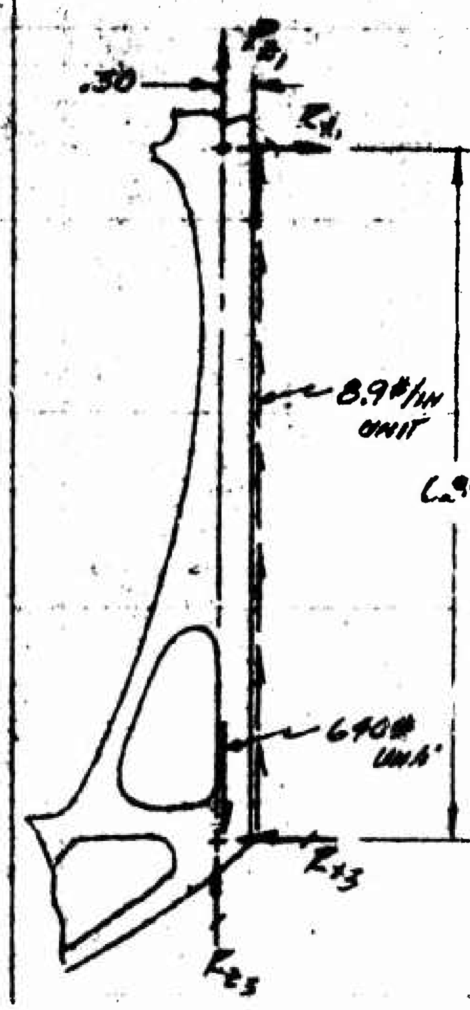
$$R_{x_3} = -R_{x_1} = \frac{6M_0}{l^3}(al - a^2)$$

$$R_{x_1} = \frac{6(18.25)}{(6.85)^3}\left[\left(\frac{6.85}{2}\right)(6.85) - \left(\frac{6.85}{2}\right)^2\right] = 4\#$$

THIS PROVIDES NO RELIEF TO THE HORIZONTAL SHEAR OF 306 # SO THAT THE AFT PORTION RESISTS THE ENTIRE LOAD.

REVISING THE APPLIED LOADS TO THE BEAM PORTIONS -

$$M_1 = M_A + 3.5(306)$$
$$= 460 + 1071$$
$$= 1531 \text{ "\# UNIT}$$



$$P_{z_1} = \frac{(263.3)(1.93) + 1531}{3.70} = 551 \text{ \# UNIT}$$

$$P_{z_2} = \frac{1531 - (263.3)(1.77)}{3.70} = 288\text{\# UNIT}$$

$$R_{z_3} = 640 - 551 - (8.9)(6.85) = 28\text{\# UNIT}$$

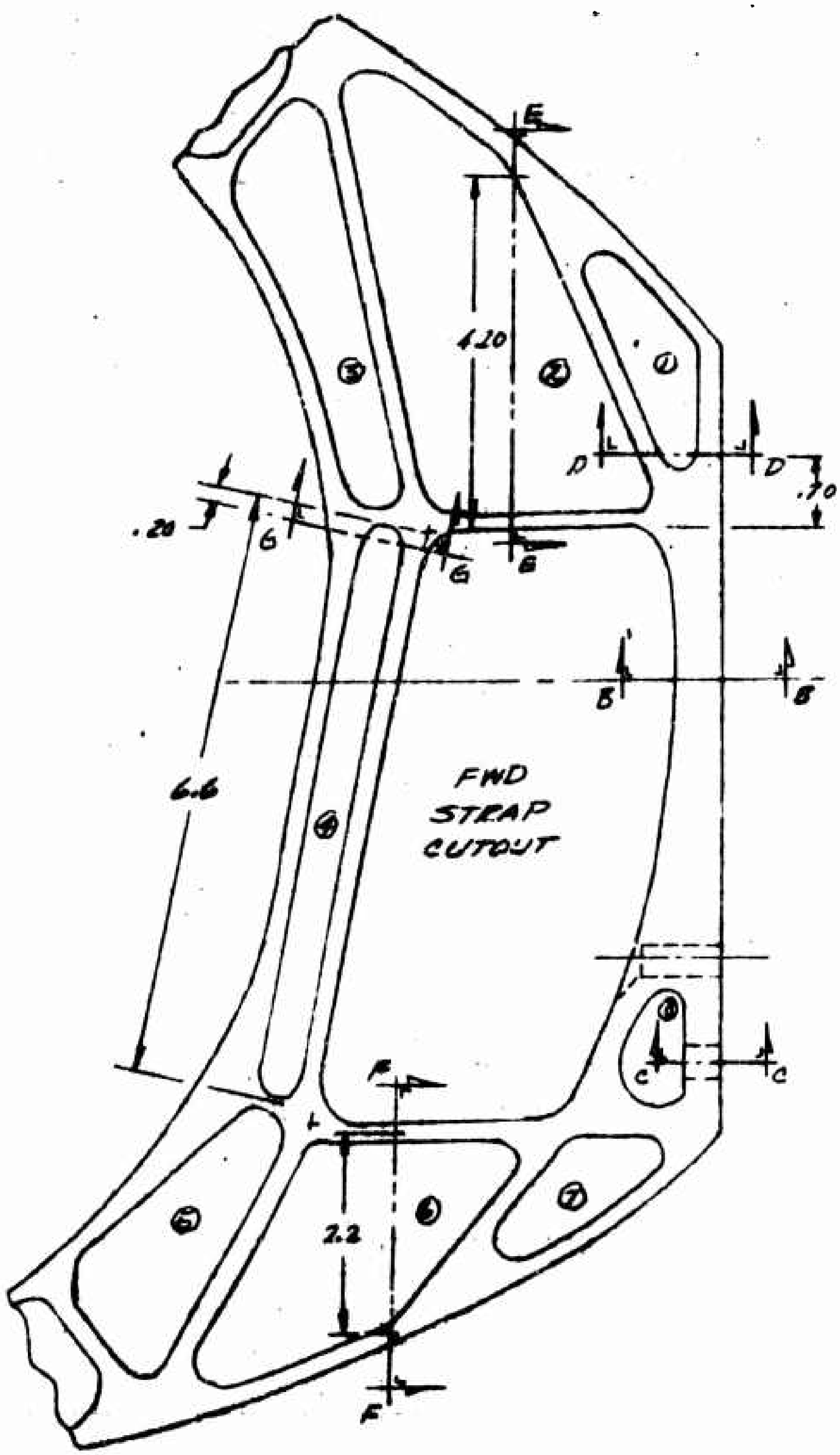
HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS HOT CYCLE ROTOR	MODEL 285	REPORT NO. 285-13	PAGE 5.2.9.35
PREPARED BY L.L. ERLE 5-19-60	ROTOR BLADE		
CHECKED BY			

INBOARD TORQUE BOX

WEIGHTED FATIGUE COND.

Z18 - STA 33.25



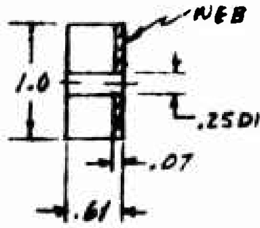
9706

INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

RIB-STA 33.25 — MAT'L - 2024-T4 PLATE

MINIMUM SECTION ON BEAM -

(UNIT × 1.732 = LIMIT)



SECTION B-B

$A = (.61)(1.00-.25) = .4575\ IN^2$

$f_c = f_t = \frac{551}{.4575} = 1204$ PSI UNIT

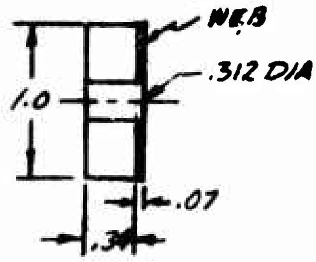
$= 2086$ PSI LIM

$F_a = \pm 11{,}000$ PSI (REF 1, TABLE 3.3.1 (b))

FOR $K_t = 3.0$, $F_a' = \pm 3660$ PSI

$M.S. = \frac{3660}{2086} - 1 = .76$

SECTION THRU FITTING ATTACHMENTS -



$A = (1.000-.312)(.34+.07) = .282\ IN^2$

$f_c = f_t = \frac{320}{.282} = 1135$ PSI UNIT

$= 1966$ PSI LIM

$F_a = \pm 3660$ PSI (REF ABOVE)

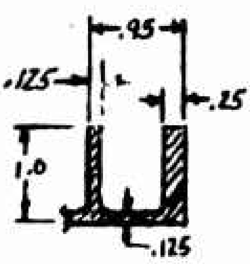
SECTION C-C

$M.S. = \frac{3660}{1966} - 1 = .87$

AT SECTION D-D A PORTION OF THE VERTICAL LOAD P_{z_1} HAS 'LAGGED' INTO WEB ② THE MAJOR PORTION ACTING AS TENSION OR COMPRESSION ON WEB ① AND THE ENCLOSING FLANGES.

$P_{SHEAR\ LAG} = \frac{.70}{4.20}(551) = 92\#$ UNIT

$P_c = P_{z_1} - P_{SL} = 551 - 92 = 459\#$ UNIT



$A = (.575)(.875) = .503\ IN^2$

$f_c = f_t = \frac{459}{.503} = 913$ PSI UNIT

$= 1580$ PSI LIM

SECTION D-D

$F_a = \pm 3660$ PSI (REF ABOVE)

$M.S. = \frac{3660}{1580} - 1 = 1.32$

INBOARD TORQUE BOX — WEIGHTED FATIGUE COND

RIB-STA 33.25

AT SECTION E-E, THE ENTIRE VERTICAL LOAD P_z, IS CARRIED AS SHEAR IN THE WEB.

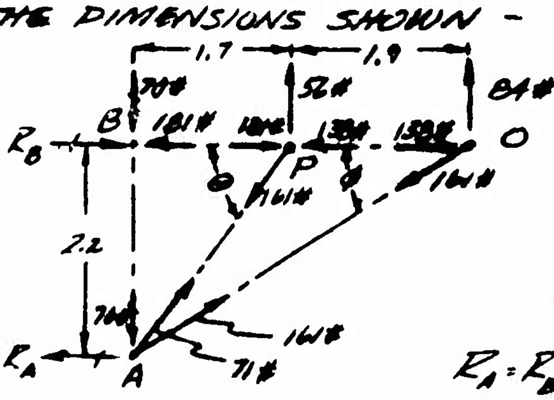
WEB $t = .125$ IN $A = (4.20)(.125) = .525$ IN^2

$$f_s = \frac{551}{.525} = 1050 \text{ PSI UNIT}$$
$$= 1820 \text{ PSI ULM}$$

$F_s = \pm 3660$ PSI $M.S. = \frac{3660}{1820} - 1 = \underline{1.02}$

IN THE PORTION OF THE RIB BELOW THE STRAP CUTOUT THE ENTIRE VERTICAL LOAD WILL BE CARRIED AS SHEAR IN WEB ⓒ AT SECTION F-F. END OF SECTION F-F THE LOAD IS CARRIED AS AXIAL LOADS IN THE FLANGES AROUND WEB ⓓ.

ASSUMING THE RIB STRUCTURE ACTS AS A TRUSS OF THE DIMENSIONS SHOWN -



$TAN\,\phi = \frac{2.2}{3.6}$; $\phi = 31.4°$

$TAN\,\theta = \frac{2.2}{1.7}$; $\theta = 52.3°$

$R_A = R_B = \frac{84(3.6) + 56(1.7)}{2.2} = 181\#$

FURTHER ASSUMPTION IS MADE THAT 60% OF R_{Z_3} IS ACTING AT POINT "O" AND 40% AT POINT "P". UNIT R_{Z_3} FOR THIS CALCULATION IS 140# DETERMINED AS FOLLOWS:

FOR THE REDESIGNED FITTING LIMIT LOAD CORRESPONDING TO 640# APPLIED LOAD IS FOUND TO BE 1300#, IN UNIT TERMS 750#. FROM THIS

$$R_{Z_3} = 750 - 551 - 8.9(6.85) = 140\# \text{ UNIT}$$

AT POINT O -

$OA = 84 \div \sin 31.4° = 161\#$ UNIT

$OP = 161 \cos 31.4° = 138\#$ UNIT

- CONT'D -

INBOARD TORQUE BOX

WEIGHTED FATIGUE COND

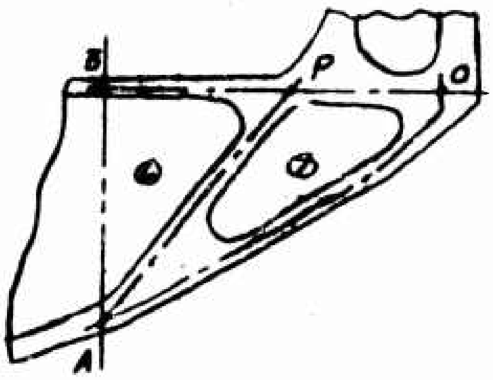
RIB - STA 33.25

AT POINT P -

$PA = 56 \div \sin 52.3° = 71\#$ UNIT

$PB = 71 \cos 52.3° + 138 = 181\#$ UNIT

THE FINAL LOADS PICTURE FOR THE TRUSS IS AS SHOWN ABOVE



FLANGE "O-P" -

(UNIT × 1.732 = LIMIT)

$t = .125$

$f_t = f_c = \frac{138}{(1.0)(.125)} = 1104$ PSI UNIT $= 1912$ PSI LIM

FLANGE "P-B" -

$t = .125$

$f_t = f_c = \frac{181}{(1.0)(.125)} = 1448$ PSI UNIT $= 2508$ PSI LIM

$F_s = \pm 3660$ PSI

$M.S. = \frac{3660}{2508} - 1 = .46$

FLANGE "P-A" -

$t = .125$

OK BY COMPARISON

SECTION F-F

WEB $t = .125$

$f_s = \frac{140}{(2.2)(.125)} = 509$ PSI UNIT $= 882$ PSI LIM

M.S. = HIGH +

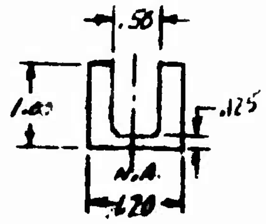
INBOARD TORQUE BOX — WEIGHTED FATIGUE COND.

RIB, STA 33.25

FROM PREVIOUS ANALYSIS IT WAS SHOWN THAT THE PORTION OF THE RIB JUST AFT OF THE STRAP CUTOUT MUST RESIST THE ENTIRE HORIZONTAL SHEAR LOAD ON THE SECTION.

$$P_{S_{UNIT}} = 306\# \quad (R_{X_6}, P_G\ 5.2.9.3.2)$$

THIS LOAD ALSO PRODUCES BENDING IN THE SEGMENT, THE MAXIMUM MOMENTS OCCURING AT THE ENDS OF THE BEAM.



$$f_s = \frac{306}{(1.2)(.125)} = 2040 \text{ PSI UNIT} \quad \text{N.G.}$$

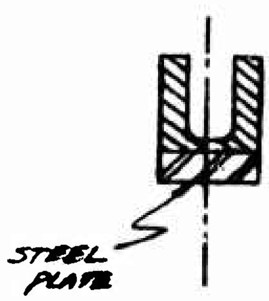
$$I_{NA} = \frac{(1.00)(1.20)^3 - (.875)(.60)^3}{12} = .135 \text{ IN}^4$$

$$f_b = \frac{(306)(3.1)(.5)}{.135} = 3513 \text{ PSI UNIT} \quad \text{N.G.}$$

SECTION G-G

A STEEL PLATE, .312 IN THICK IS ADDED TO THE STRUCTURE.

$$I'_{STEEL} = \frac{.312\,(1.20)^3}{12} = .054 \text{ IN}^4$$



LOAD IS DISTRIBUTED ACCORDING TO EI OF THE MATERIAL. THE EQUIVALENT MOMENT OF INERTIA OF THE STEEL

$$I_{STEEL} = 2.9 \times .054 = .156$$

THE ALUMINUM SECTION WILL RECEIVE

$$\frac{.135}{.135 + .156} \times 306 = 142\# \text{ UNIT}$$

SHEAR STRESS –

$$f_s = \frac{142}{(1.20)(.125)} = 947 \text{ PSI UNIT}$$
$$= 1640 \text{ PSI LIM}$$

$$F_s = (.60)(\pm 3660) = \pm 2200 \text{ PSI} \qquad M.S. = \frac{2200}{1640} - 1 = \underline{.34}$$

BENDING STRESS –

$$f_b = \frac{(142)(3.1)(.5)}{.135} = 1630 \text{ PSI UNIT}$$
$$= 2830 \text{ PSI LIM}$$

$$F_a = \pm 3660 \text{ PSI (REF 1)}$$

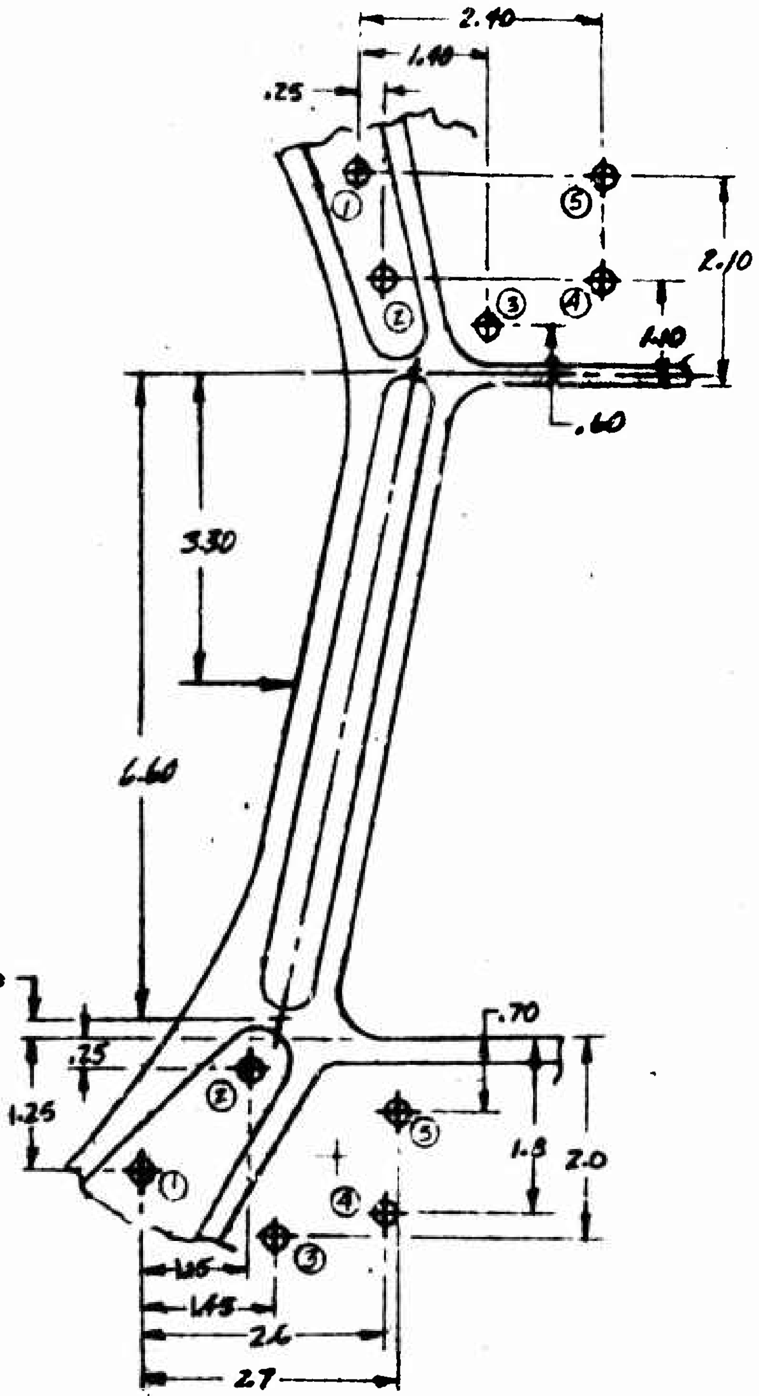
$$M.S. = \frac{3660}{2830} - 1 = \underline{.29}$$

INBOARD TORQUE BOX WEIGHTED FATIGUE COND

RIB - STA 58.25

ATTACHMENT OF STEEL PLATE TO RIB STRUCTURE

ALL BOLTS .250 DIA. PLATE H.T. 140-160 KSI



INBOARD TORQUE BOX

WEIGHTED FATIGUE COND

RIB - STA 33.25

UPPER BOLT PATTERN -

BOLT	X	X^2	Y	Y^2
①	0	0	2.10	4.41
②	.25	.06	1.10	1.21
③	1.40	1.96	.60	.36
④	2.40	5.76	1.10	1.21
⑤	2.40	5.76	2.10	4.41
Σ	6.45	13.54	7.00	11.60

$\bar{X} = \frac{6.45}{5} = 1.29$

$\bar{Y} = \frac{7.00}{5} = 1.40$

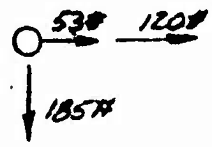
$I_p = 13.54 + 11.60 - 5(\overline{1.40}^2 + \overline{1.29}^2) = 7.34$

$M_{C.G.} = (4.6)(103)(1.732) = 1220$ "# LIM

DIRECT LOAD $= \frac{(103)(1.732)}{5} = 53$ # LIM

BOLT ⑤ -

$P_{X_M} = \frac{1220\,(.70)}{7.34} = 120$ # LIM.



$P_{Y_M} = \frac{1220\,(1.11)}{7.34} = 185$ # LIM

$P_{BOLT} = 173 \overset{+}{\longrightarrow} 185 = 252$ # LIM

$f_{br} = \frac{252}{(.25)(.312)} = 5360$ PSI LIM

$F_{br} = 7650$ PSI
(REF PG 5.2.9.4.0)

$M.S. = \frac{7650}{5360} - 1 = \underline{\underline{.43}}$

LOWER BOLT PATTERN -

BOLT	X	X^2	Y	Y^2
①	0	0	1.25	1.56
②	1.15	1.32	.25	.06
③	1.45	2.10	2.00	4.00
④	2.6	6.76	1.80	3.24
⑤	2.7	7.29	.70	.49
Σ	7.90	17.47	6.00	9.35

$\bar{X} = \frac{7.90}{5} = 1.58$

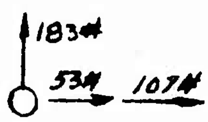
$\bar{Y} = \frac{6.00}{5} = 1.20$

$I_p = 17.47 + 9.35 - 5(\overline{1.58}^2 + \overline{1.20}^2) = 7.12$

$M_{C.G.} = 4.8(103)(1.732) = 1272$ "# LIM

DIRECT LOAD $= \frac{(103)(1.732)}{5} = 53$ # LIM

BOLT ④ -



$P_{X_M} = \frac{1272\,(.60)}{7.12} = 107$ # LIM

$P_{Y_M} = \frac{1272\,(1.02)}{7.12} = 183$ # LIM

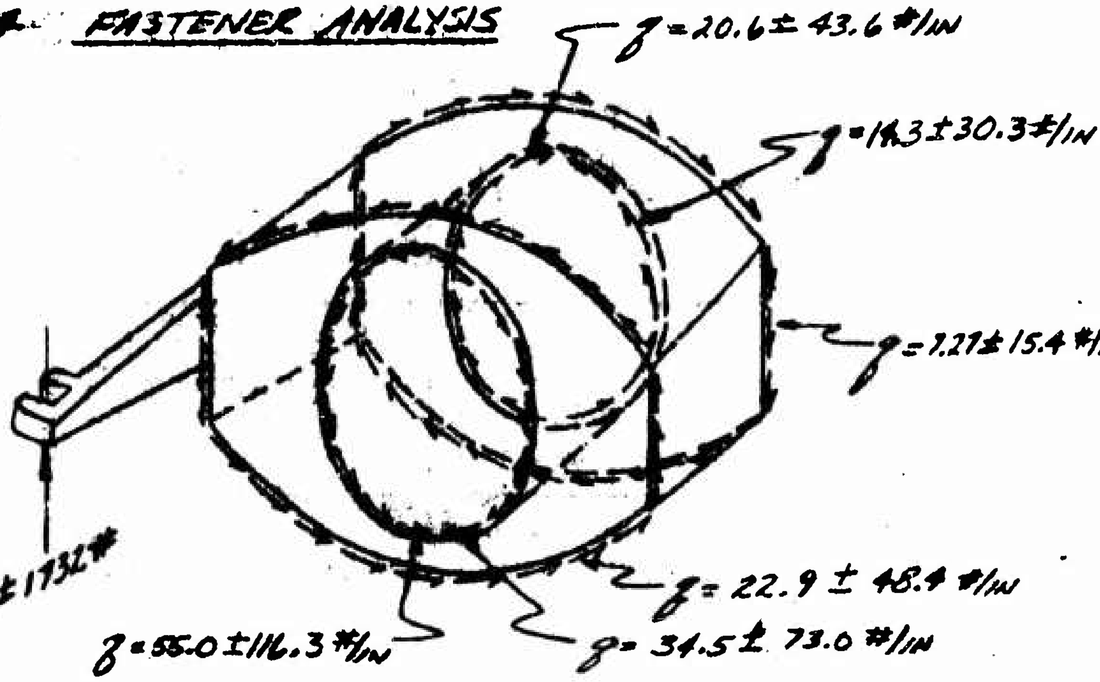
$P_{BOLT} = 160 \overset{+}{\longrightarrow} 183 = 243$ # LIM

$M.S. = \frac{7650}{5170} - 1 = \underline{\underline{.48}}$

$f_{br} = \frac{243}{(.312)(.25)} = 5170$ PSI LIM

INBOARD TORQUE BOX WEIGHTED FATIGUE COND

5.2.9.4 FASTENER ANALYSIS



TO DETERMINE THE FATIGUE STRENGTH OF ANY PANEL, THE LOAD PER RIVET IS DETERMINED AND COMPARED TO AN ALLOWABLE GIVEN IN REF 6, PAGE 29, AS FOLLOWS:

RIVET DIA	LOAD PER RIVET, LB		SHEET BEARING STRESS
3/16	185	← GIVEN	15,300 PSI
5/32	127	RATIO TO 3/16 DIA	15,300 PSI
1/8	82		15,300 PSI

HOWEVER, DUE TO STRESS CONCENTRATION FACTORS THE SHEET BEARING STRESS IS REDUCED BY ONE-HALF

$$F_{br} = 7650 \text{ PSI}$$

THE LARGEST SHEAR FLOWS OCCUR IN THE INNER TUBE

$q = 55.0 \pm 116.3$ #/IN $t = .051$ AD5 RIVETS 1.0 O.C.

$q_{max} = 55.0 + 116.3 = 171.3$ #/IN LIM

$q_{mean} = 85.65$ #/IN LIM

$$f_{br} = \frac{85.65}{(.051)(.156)} = 10,765 \text{ PSI LIM}$$

- CONT'D -

INBOARD TORQUE BOX WEIGHTED FATIGUE COND

FASTENER ANALYSIS (CONT'D)

CHANGE RIVETS TO AD6 @ .75 SPACING

$$f_{br} = \frac{(.75)(85.65)}{(.051)(.189)} = 6670 \text{ PSI LIM}$$

$$M.S. = \frac{7650}{6670} - 1 = \underline{\underline{.15}}$$

$q = 34.5 \pm 73.0$ #/IN $t = .051$ AD5 RIVETS 1.0 O.C.

$q_{MAX} = 34.5 + 73.0 = 109.5$ #/IN LIM

$q_{MEAN} = 54.75$ #/IN LIM

$$f_{br} = \frac{54.75}{(.051)(.156)} = 6900 \text{ PSI LIM} \qquad M.S. = \frac{7650}{6900} - 1 = \underline{\underline{.11}}$$

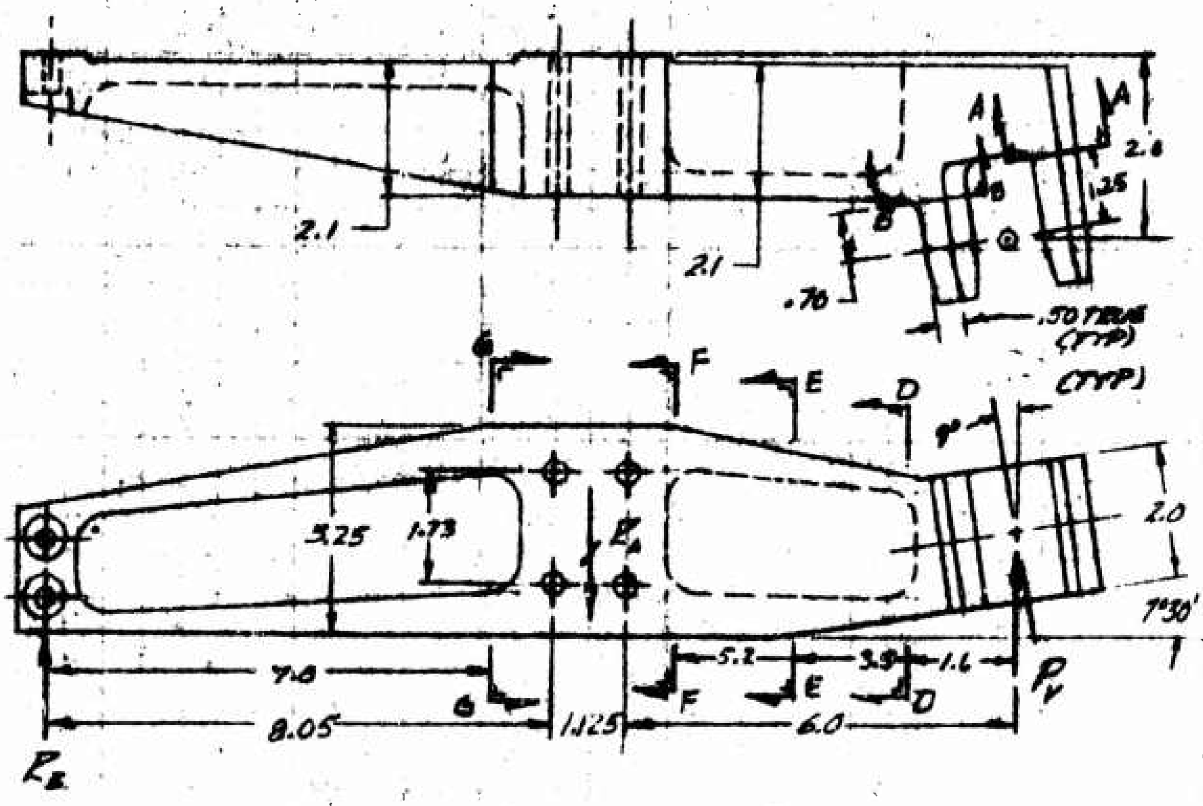
THE REMAINDER OF THE BOX, HAVING SUBSTANTIALLY LOWER SHEAR FLOWS IS OK BY INSPECTION.

SHEET SHEAR STRESSES

PANEL	t	q_{MAX}	f_s
UPPER SKIN	.051	71.3 #/IN	1400 PSI
LOWER SKIN	.063	71.3 #/IN	1130 PSI
FORWARD WEB	.063	71.3 #/IN	1130 PSI
REAR WEB	.063	71.3 #/IN	1130 PSI
TUBE FWD SECTION	.051	171.3 #/IN	3360 PSI
TUBE AFT SECTION	.051	109.5 #/IN	2150 PSI

5.2.9.5 285-0190 FEATHERING ARM

MAT'L - AL. ALLOY 2014-T6



P_V = 1664 ± 2665 # LIM (2½G MANEUVER COND) (TABLE 5.4.2.2-1)
= 819 ± 1732 # LIM (WEIGHTED FATIGUE COND) (TABLE 5.4.2.2-2)

CALCULATIONS MADE FOR WEIGHTED FATIGUE COND ONLY

$$R_B = \frac{6.0}{8.05} P_V = \frac{6.0}{8.05}(819 \pm 1732) = 610 \pm 1291 \text{ \# LIM}$$

FITTING ATTACHMENTS -

1.) ATTACHMENT TO STA 24.25 RIB - (4) .312 DIA BOLTS
THE BOLTS RESIST THE APPLIED MOMENT AS A COUPLE, THE UPPER BOLTS IN COMPRESSION, LOWER IN TENSION

$$M = 2.8(819 \pm 1732) = 2293 \pm 4850 \text{ "\# LIM}$$

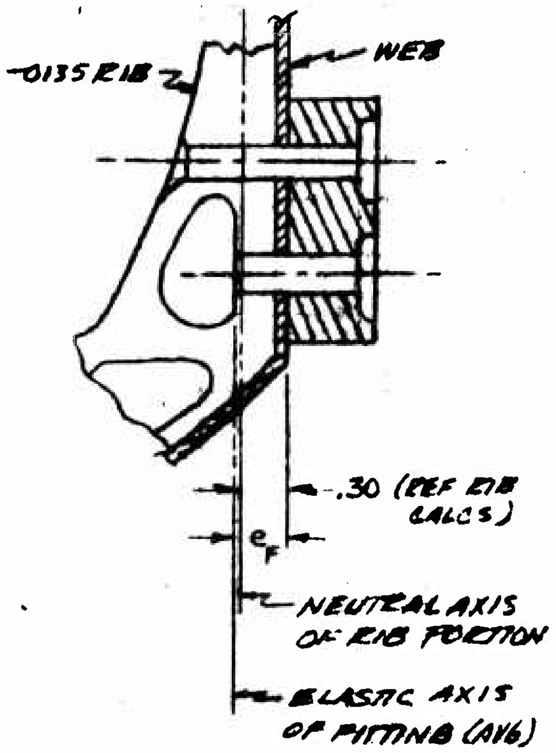
$$P_{BOLT} = \frac{2293 \pm 4850}{(2)(1.73)} = 663 \pm 1402 \text{ \# LIM}$$

BOLT TORQUE WILL EASILY COMPENSATE FOR THIS LOADING. VERTICAL SHEAR IN EACH BOLT IS SMALL SO NO ANALYSIS IS MADE FOR THIS LOADING.

285-0140 FEATHERING ARM (CONT'D)

FITTING ATTACHMENTS (CONT'D)

2.) ATTACHMENT TO STA 33.25 RIB - (2) .312 DIA BOLTS



$e_F = .40$ (AVG)

SINCE THE AVERAGE POSITION OF THE ELASTIC AXIS OF THE ARM FALLS APPROXIMATELY ON THE NEUTRAL AXIS OF THE PORTION OF THE RIB REACTING THE R_B LOAD, NO TWIST IS IMPOSED ON THE SECTION.

ATTACHING BOLTS OK BY COMPARISON TO STA 24.25 RIB ATTACHMENT.

BEARING OF BOLTS IN HOLES -

$$f_{br} = \frac{(610 \pm 1291)}{(2)(.312)(.312)} = 3130 \pm 6640 \text{ PSI LIM}$$

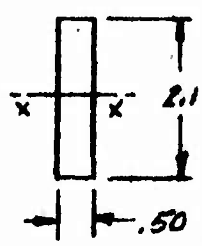
$$F_d = 7650 \text{ PSI (REF PG 5.2.9.4.0)}$$

$$M.S. = \frac{7650}{6640} - 1 = \underline{\underline{.15}}$$

285-0140 FEATHERING ARM (CONT'D)

LUGS ANALYSIS

THE VERTICAL COMPONENT OF THE APPLIED LOAD IS EQUALLY DIVIDED BETWEEN THE LUGS



SECTION A-A

$$f_s = \frac{(819 \pm 1732)\cos 9^\circ}{(2.1)(.50)(2)} = 400 \pm 850 \text{ PSI LIM}$$

$$F_s = (.60)(\pm 9000) = \pm 5400 \text{ PSI (REF 1, TABLE 3.3.1 (b))}$$

M.S. = HIGH +

$$I_{xx} = \frac{(.50)(2.1)^3}{12} = .386 \text{ IN}^4$$

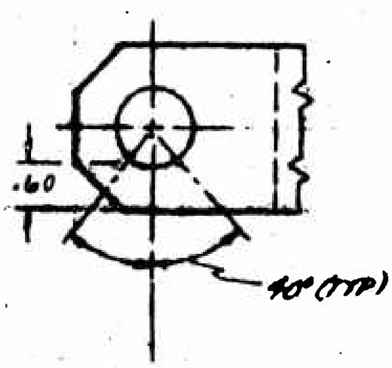
$$M_{xx} = \frac{(819 \pm 1732)(\cos 9^\circ)(1.25)}{2} = 506 \pm 1069 \text{ "\# LIM}$$

$$f_b = \frac{(506 \pm 1069)(1.05)}{.386} = 1376 \pm 2907 \text{ PSI LIM}$$

$$F_b = \pm 9000 \text{ PSI (REF 1, TABLE 3.3.1 (b))}$$

$$M.S. = \frac{9000}{2907} - 1 = \underline{\underline{2.10}}$$

SHEAR-OUT OF LUG -



$$A_{s.o.} = (2)(.60 \times .50) = .60 \text{ IN}^2$$

$$f_{s.o.} = \frac{(819 \pm 1732)}{(2)(.60)} = 683 \pm 1445 \text{ PSI LIM}$$

$$F_s = \pm 5400 \text{ PSI (REF. ABOVE)}$$

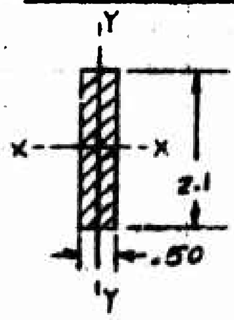
FOR TITE LUG ASSUME $K_t = 3.0$

$$f_{s.o.} = (3.0)(1445) = 4340 \text{ PSI}$$

$$M.S. = \frac{5400}{4340} - 1 = \underline{\underline{.25}}$$

285-0140 FEATHERING ARM (CONT'D)

LUG ANALYSIS (CONT'D)



SECTION B-B

$$I_{XX} = \frac{(.50)(2.1)^3}{12} = .386\ IN^4$$

$$I_{YY} = \frac{(2.1)(.50)^3}{12} = .0219\ IN^4$$

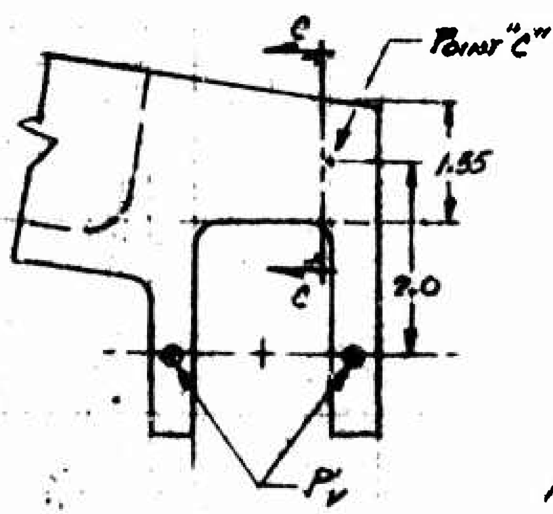
$$M_{XX} = \frac{(819 \pm 1732)(\cos 9°)(.70)}{2} = 283 \pm 600\ \text{"\# LIM}$$

$$M_{YY} = \frac{(819 \pm 1732)(\sin 9°)(.35)}{2} = 22 \pm 47\ \text{"\# LIM}$$

THE HORIZONTAL COMPONENT OF THE APPLIED LOAD IS REACTED ENTIRELY BY THIS LUG, THE POINT OF APPLICATION OF THE LOAD BEING ON THE MEDIAN DIAMETER OF THE BUSHING.

$$f_b = \frac{(283 \pm 600)(1.05)}{.386} + \frac{(22 \pm 47)(.35)}{.0219} = 1020 \pm 2168\ PSI\ LIM$$

$F_b = \pm 9000$ PSI (REF 1) M.S. = HIGH +



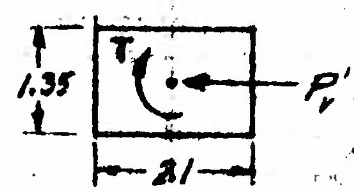
TRANSFERRING THE LOAD P_V' TO POINT "C" AS SHOWN PRODUCES THE TORSIONAL MOMENT "T" WHICH IS REACTED BY SECTION C-C

$$P_V' = \frac{819 \pm 1732}{2}(\cos 9°) = 405 \pm 855\ \text{\# LIM}$$

$$T = (405 \pm 855)(2.0) = 810 \pm 1710\ \text{"\# LIM}$$

FROM REF 2, CHAP 9, TABLE IX, CASE 4

$$f_{ST} = \frac{T\left[3\left(\frac{2.1}{2}\right) + 1.8\left(\frac{1.35}{2}\right)\right]}{8\left(\frac{2.1}{2}\right)^2\left(\frac{1.35}{2}\right)^2} = 1.09T$$



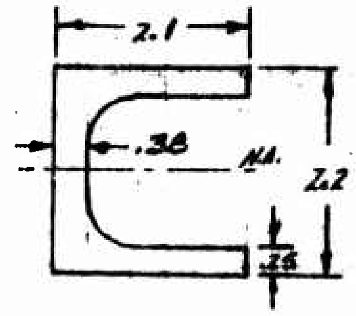
SECTION C-C

$$f_{ST} = 1.09(810 \pm 1710) = 883 \pm 1864\ PSI\ LIM$$

$$F_s = (.60)(\pm 9000) = \pm 5400\ PSI\ (REF\ 1)$$

$$M.S. = \frac{5400}{1864} - 1 = \underline{1.90}$$

285-0140 FEATHERING ARM (CONT'D)



SECTION D-D

$$I_{NA} = \frac{2.1(2.2)^3 - 1.72(1.7)^3}{12} = 1.16\ IN^4$$

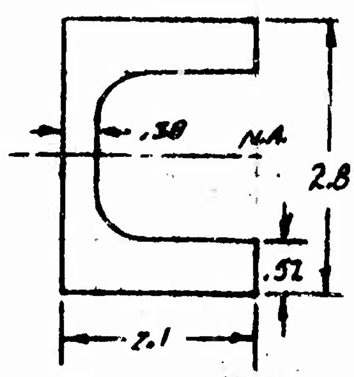
$$M_{D-D} = 1.6(819 \pm 1732) = 1310 \pm 2771\ "\#\ LIM$$

$$f_b = \frac{(1310 \pm 2771)(1.1)}{1.16} = 1242 \pm 2627\ PSI\ LIM$$

$F_s = \pm 3500$ PSI $\quad M.S. = \frac{3500}{2627} - 1 = \underline{.33}$

$$f_s = \frac{819 \pm 1732}{(2.2)(.38)} = 980 \pm 2080$$

$F_s = (.60)(\pm 9000) = \pm 5400$ PSI $\quad M.S. = \frac{5400}{2080} - 1 = \underline{1.60}$



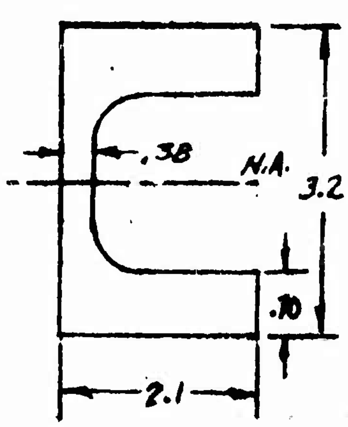
SECTION E-E

$$I_{NA} = \frac{2.1(2.8)^3 - 1.72(1.76)^3}{12} = 3.07\ IN^4$$

$$M_{E-E} = 3.5(819 \pm 1732) = 2867 \pm 6062\ "\#\ LIM$$

$$f_b = \frac{(2867 \pm 6062)(1.4)}{3.07} = 1307 \pm 2764\ PSI\ LIM$$

$F_b = \pm 9000$ PSI (REF 1) $\quad M.S. = \frac{9000}{2764} - 1 = \underline{2.25}$



SECTION F-F

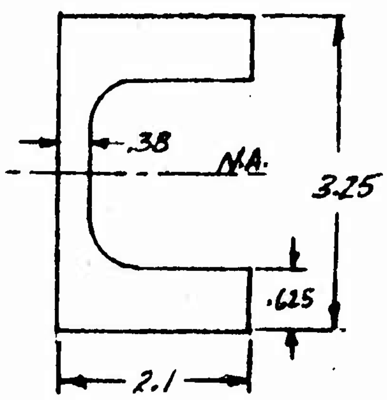
$$I_{NA} = \frac{2.1(3.2)^3 - 1.72(1.8)^3}{12} = 4.90\ IN^4$$

$$M_{F-F} = 5.2(819 \pm 1732) = 4259 \pm 9006\ "\#\ LIM$$

$$f_b = \frac{(4259 \pm 9006)(1.6)}{4.90} = 1390 \pm 2940\ PSI\ LIM$$

$F_b = \pm 9000$ PSI $\quad M.S. = \frac{9000}{2940} - 1 = \underline{2.06}$

285-0140 FEATHERING ARM (CONT'D)



SECTION 6-6

$$I_{NA} = \frac{2.1(3.25)^3 - 1.72(2.00)^3}{12} = 4.86 \text{ IN}^4$$

$$M_{6-6} = 7.0(610 \pm 1291) = 4270 \pm 9037 \text{ "\# LIM}$$

$$f_b = \frac{(4270 \pm 9037)(1.625)}{4.86} = 1426 \pm 3018 \text{ PSI LIM}$$

$$F_a = \pm 9000 \text{ PSI} \quad \text{(REF 1)}$$

$$M.S. = \frac{9000}{3018} - 1 = \underline{\underline{1.98}}$$

INBOARD TORQUE BOX

5.29.0 DROOP STOP CONDITION – LOADING ANALYSIS

LIMIT BLADE MOMENT – GROUND FLAPPING CONDITION

M = 125,810 (REF BASIC LOADS DATA, SECTION 4)

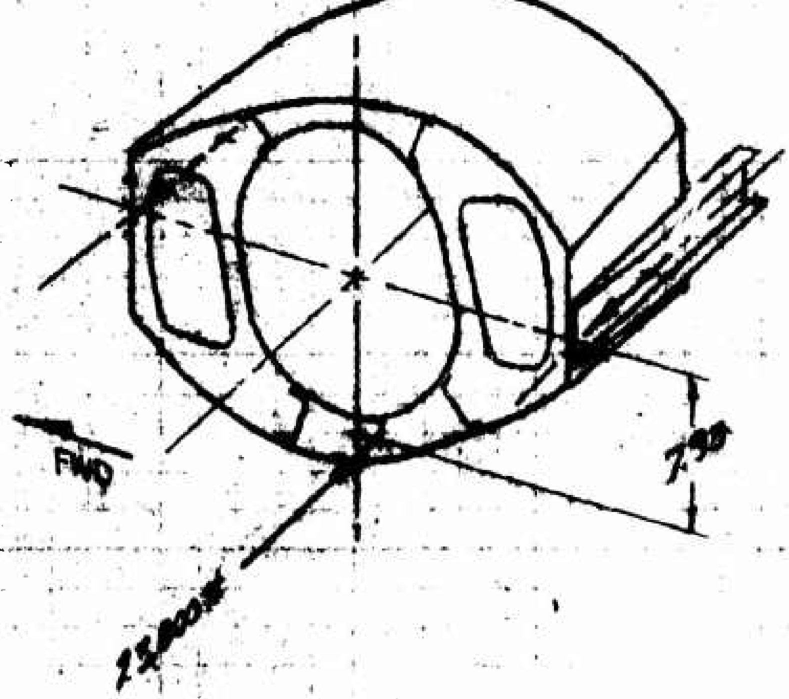
M_{ULT} = 1.5 x 125,810 = 188,700 IN-#

℄ OF DROOP STOP LOCATED @ 8.40 BELOW ℄ OF SPARS IN NEUTRAL POSITION

MINIMUM ARM OCCURS WITH BLADE NOSE DOWN 19.6° FROM THE NEUTRAL POSITION

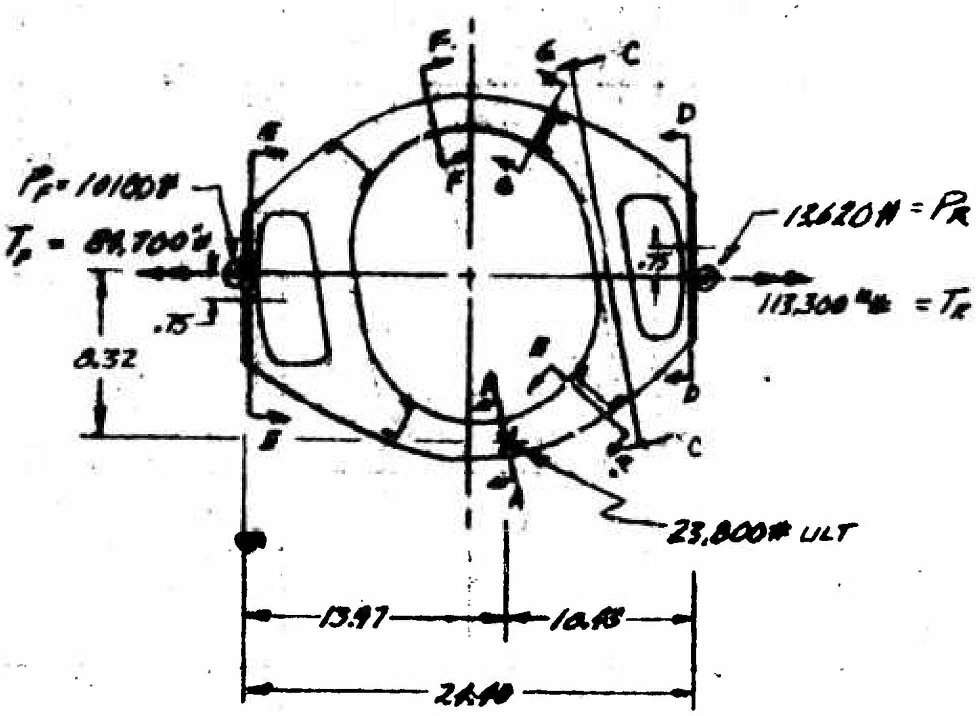
MIN. ARM = 8.40 COS 19.6° = 7.93 IN

DROOP STOP MAXIMUM LOAD = $\frac{188,700}{7.93}$ = 23,800 # ULT



INBOARD TORQUE BOX - DROOP STOP COND.

LOADING ANALYSIS - CONT'D



$$P_R = \frac{23800 \times 13.97}{24.40} = 13{,}620\#\ ULT$$

$$P_F = \frac{23{,}800 \times 10.43}{24.40} = 10{,}180\#\ ULT$$

$$T_R = 13{,}620 \times 8.32 = 113{,}300"\#\ ULT$$

$$T_F = 10{,}180 \times 8.32 = 84{,}700"\#\ ULT$$

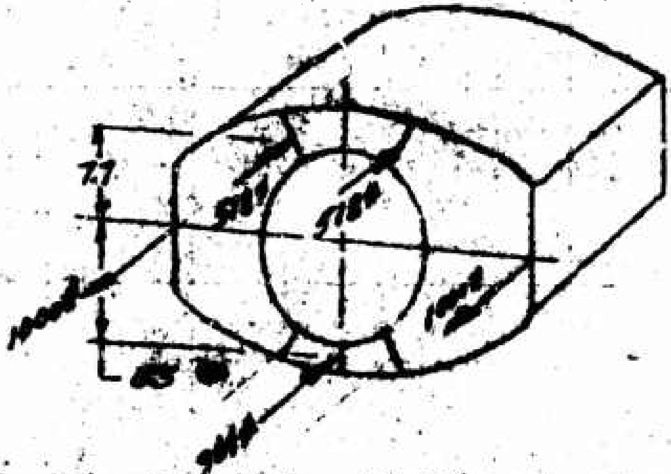
INBOARD TORQUE BOX DROOP STOP COND

5.29.7 UNIT LOADS ANALYSIS

FOR SIMPLICITY, THE BOX IS CONSERVATIVELY ASSUMED SYMMETRICAL ABOUT AXIS THRU SECTIONS A-A & F-F.

THE LOADING IS THEN BROKEN DOWN INTO TWO CASES EMPLOYING A UNIT STRAP LOAD = 1000#

CASE I

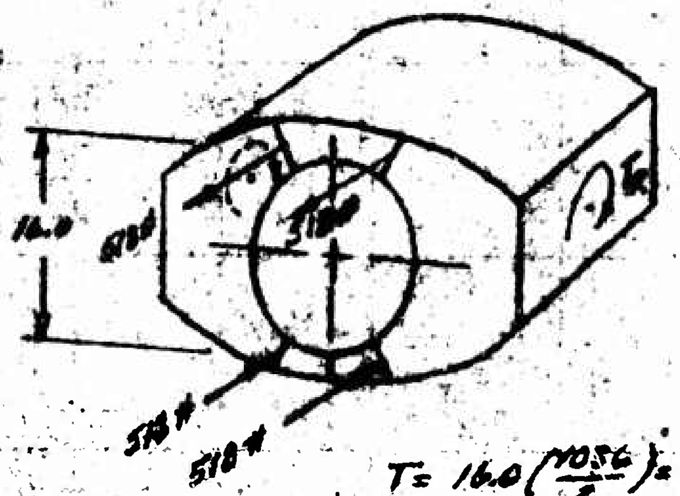


$$P_{UPPER} = 2000\left(\frac{8.3}{7.7+8.3}\right)\left(\frac{1}{2}\right)$$

$$= 518\# \text{ UNIT}$$

$$P_{LOWER} = 2000\left(\frac{7.7}{7.7+8.3}\right) = 364\# \text{ UNIT}$$

CASE II



$$T = 16.0\left(\frac{1036}{2}\right) = 8300\text{"\# UNIT}$$

$$T_R = 8300 + (.75)(1000) = 9050\text{"\# UNIT}$$

$$T_F = 8300 - (.75)(1000) = 7550\text{"\# UNIT}$$

UNBALANCED TORQUE BOX — DROOP STOP CAMS

UNIT LOADS ANALYSIS - CONT'D

CASE II a

FROM CASE I & II a COMBINED:

BOX AT A-A

$q_1 = q_3 = \frac{1000}{(2)(9.0)} = 55.6$ #/in

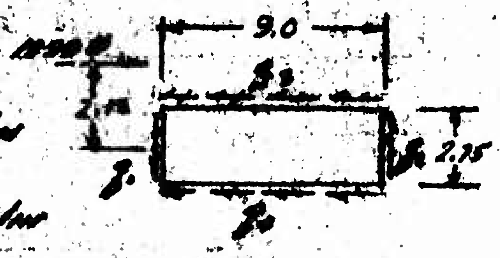
$q_2 = q_4 = 0$

BOX AT B-B

$q_1 = q_2 = \frac{(1000)(2.15)}{(2)(9)(2.75)} = 42.8$ #/in

$q_3 = \frac{1000}{(2)(9)} + 42.8 = 98.4$ #/in

$q_4 = 55.6 - 42.8 = 12.8$ #/in

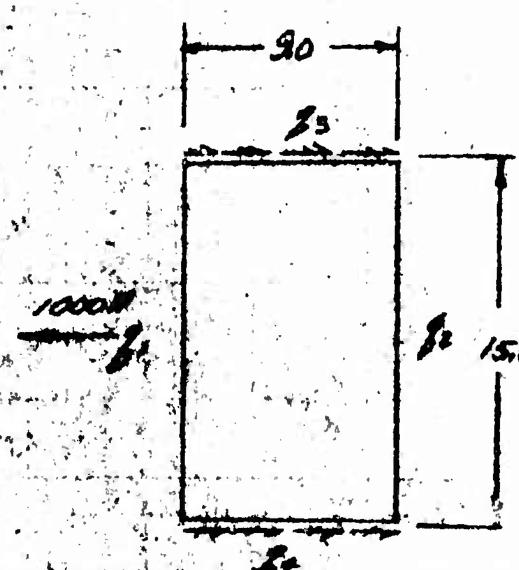


FROM CASE I

BOX AT C-C

$q_1 = q_2 = 0$

$q_3 = q_4 = \frac{1000}{(2)(9)} = 55.6$ #/in



HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS: Hot Cycle Rotor MODEL: 285 REPORT NO. 285-13 PAGE 5.2.9.7.2

Rotor Blade

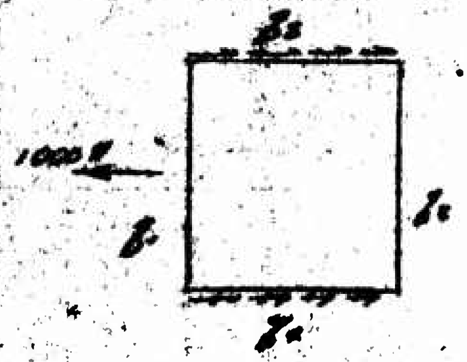
Inboard Torque Box — Droop Stop Cond

Unit Loads Analysis - Cont'd

Box at D-D

$q_1 = q_4 = 0$

$q_2 = q_3 = \frac{1000}{(2)(9)} = 55.6 \#/in$

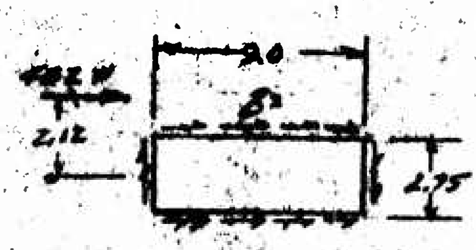


Box at B-B

$q_1 = q_3 = \frac{(482)(2.12)}{(2)(9)(2.75)} = 20.6 \#/in$

$q_2 = \frac{482}{(2)(9)} + 20.6 = 47.4 \#/in$

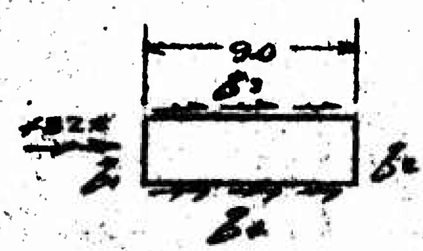
$q_4 = 26.8 - 20.6 = 6.2 \#/in$



Box at A-A

$q_2 = q_4 = \frac{482}{(2)(9)} = 26.8 \#/in$

$q_1 = q_3 = 0$



ROTOR BLADE

INBOARD TORQUE BOX — DROOP STOP COND

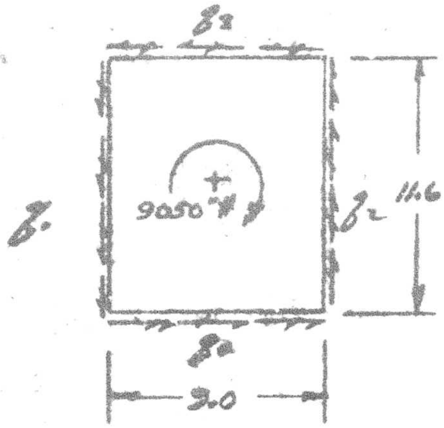
UNIT LOADS ANALYSIS – CONT'D

FROM CASE II

SECTION MID-WAY BETWEEN C-C & D-D

$$q_1 = q_2 = q_3 = q_4 = \frac{9050}{(2)(9)(11.6)}$$

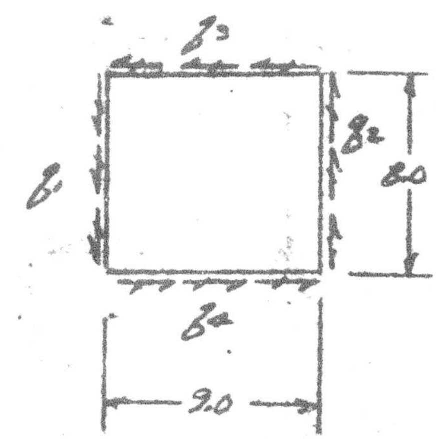
$$= 43.3 \text{ \#/in}$$



BOX AT D-D

$$q_3 = q_4 = 43.3 \text{ \#/in}$$
(SEE ABOVE)

$$q_T = \frac{9050}{(2)(9)(8)} = 62.8 \text{ \#/in}$$



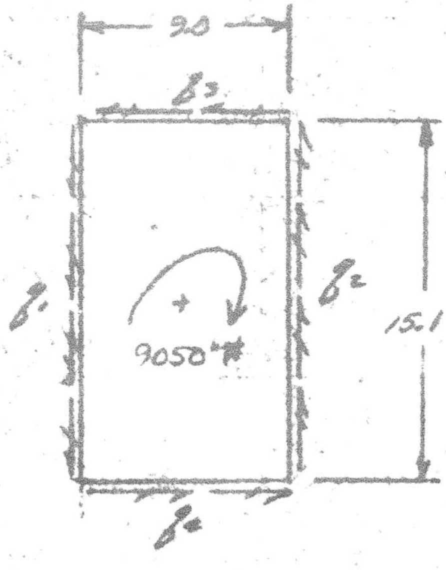
$$q_1 = q_2 = \frac{(62.8 - 43.3)(18)}{16} + 62.8 = 84.7 \text{ \#/in}$$

ROTOR BLADE

INBOARD TORQUE BOX — DROOP STOP COND.

UNIT LOADS ANALYSIS - CONT'D

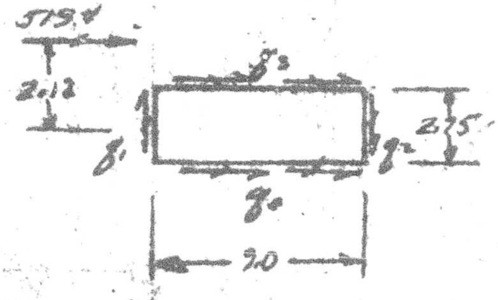
BOX AT C-C



$$q_1 = q_2 = q_3 = q_4$$

$$= \frac{9050}{(2)(9)(15.1)} = 33.3 \ \#/\mathrm{IN}$$

BOX AT B-B



$$q_1 = q_2 = \frac{(519)(2.12)}{(2)(9)(2.75)} = 22.2 \ \#/\mathrm{IN}$$

$$q_4 = \frac{519}{(2)(9)} + 22.2 = 51.0 \ \#/\mathrm{IN}$$

$$q_3 = 28.8 - 22.2 = 6.6 \ \#/\mathrm{IN}$$

BOX AT A-A

$$q_1 = q_2 = 0$$

$$q_3 = q_4 = \frac{519}{(2)(9)} = 28.8 \ \#/\mathrm{IN}$$

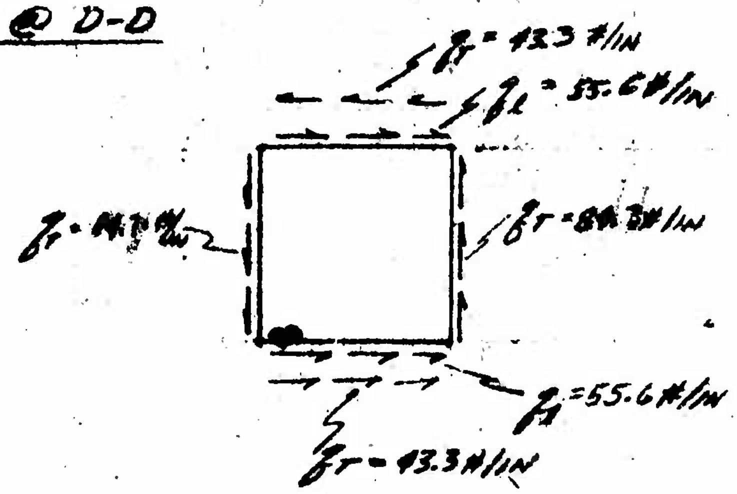
ROTOR BLADE

INBOARD TORQUE BOX DROOP STOP COND

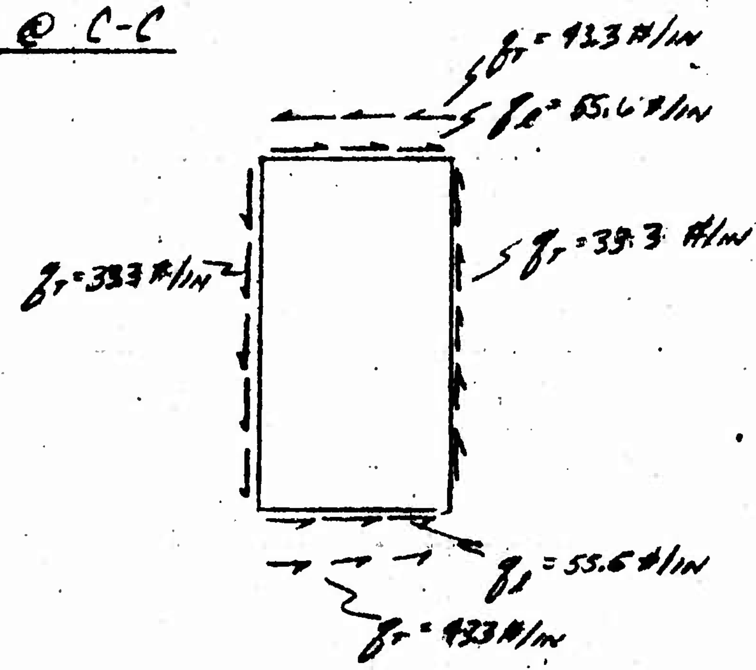
UNIT LOADS ANALYSIS - CONT'D

TOTAL SHEAR FLOWS

Box @ D-D



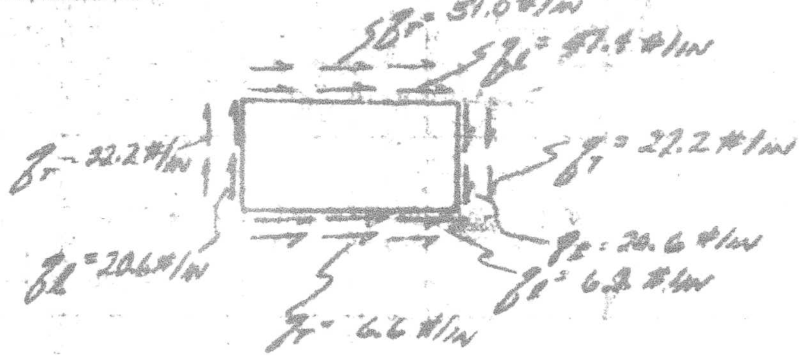
Box @ C-C



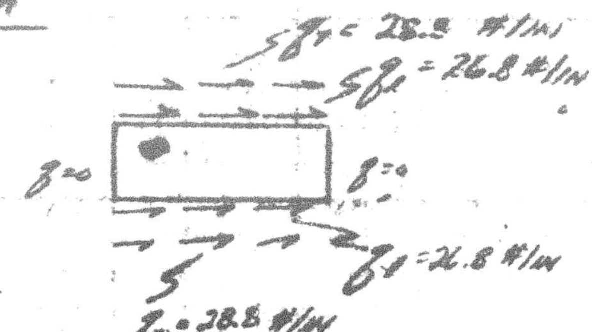
INBOARD TORQUE BOX DROOP STOP COND

UNIT LOADS ANALYSIS – CONT'D

Box @ B-B



Box @ A-A



ANALYSIS: HOT CYCLE ROTOR MODEL: 285 REPORT NO. 285-13 PAGE

PREPARED BY: L.L. Cole 3-2-60

CHECKED BY:

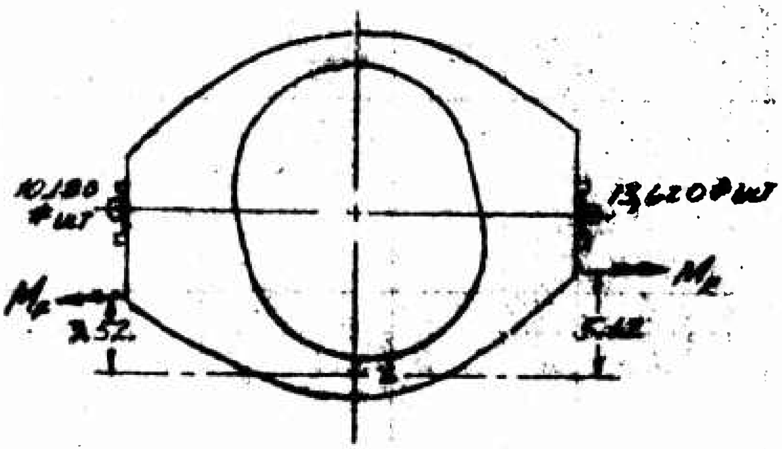
ROTOR BLADE

INBOARD TORQUE BOX — DROOP STOP COND.

5.2.9.8 RIBS ANALYSIS - 285-0134, 285-0135

MAT'L 2024-T4 PLATE

NOTE:
FOR SIMPLICITY, EACH RIB IS CONSIDERED TO HAVE THE SAME LOADING PATTERN.



REAR BOX

(LOADS REF PG 5.2.9.6.1)

$M_F = 3.52 \times 10180 = 35,834$ "# ULT
$M_R = 5.12 \times 13620 = 69,734$ "# ULT

MULTIPLY q_R BY $\frac{13,620}{1000} = 13.62$

MULTIPLY q_T BY $\frac{69,734}{9050} = 7.71$

@ SECTION D-D $q = (13.62)(0) + (7.71)(84.7) = 653$ #/IN ULT

@ SECTION BETWEEN C-C & D-D $q = (7.71)(43.3) = 334$ #/IN ULT

@ SECTION C-C $q = (13.62)(0) + (7.71)(33.3) = 257$ #/IN ULT

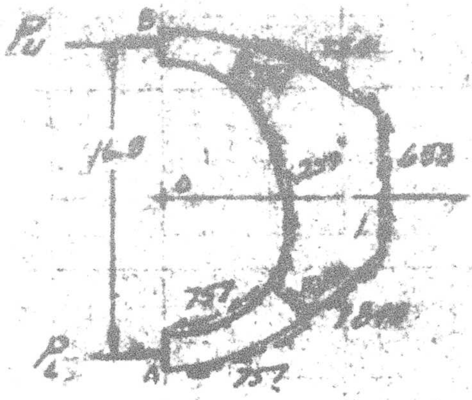
IN THE LOWER SKIN $q = \frac{13,620}{9.0} = 1514$ #/IN ULT

ROTOR BLADE

INBOARD TORQUE BOX DROOP STOP COND

RIBS ANALYSIS - CONT'D

REAR BOX



SHEAR FLOW	X	Z	HORIZ FORCE	VERT FORCE	2A	M_o
334	7.45	3.60	+2488	-1202	85.8	+28,657
257 } 257	1.80	13.70	+308	+3521	82.4	-21,177
1014	2.30	1.80	-2332	+1825	1.5	-1521
1848	3.90	3.10	-7207	-5729	54.0	+99,792
653	0	8.0	0	+5224	96.2	-62,819
757	3.30	2.30	-2498	-1741	29.0	+21,953
757	5.20	2.40	-3936	-1817	40.9	+30,961
Σ			-13,793#	+81#		+95,846"#

$\Sigma M_A = 0 = 95,846 + 16.8 P_U - 13,793(8.4)$

$P_U = 1192$ # ULT

$P_L = 13,793 - 1192$

$P_L = 12,601$ # ULT

INBOARD TORQUE BOX — DROOP STOP COND

RIBS ANALYSIS - CONT'D

MATERIAL ALLOWABLES — MAT'L - 2024-T4 PLATE

CALCULATED OPERATING TEMPERATURE OF THE STRUCTURAL COMPONENTS IN THIS SECTION IS INDICATED AS 300°F (REF SECTION 1)

BASED ON A 1000 HOUR OPERATING TIME:

$$F_{tu} = (.75)(58,000) = 43,500 \text{ PSI}$$

(REF 4 FIG. 3.2.3.1.1 (a))

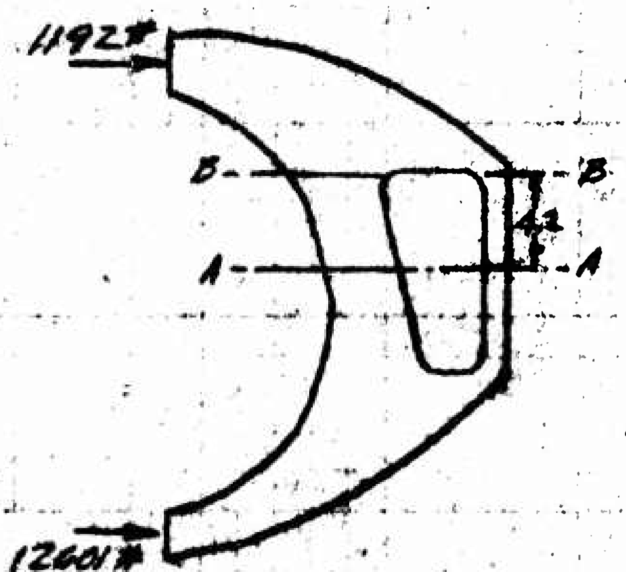
INBOARD TORQUE BOX

DROOP STOP COND

RIBS ANALYSIS - CONT'D

RIB STA 24.25

REAR BOX

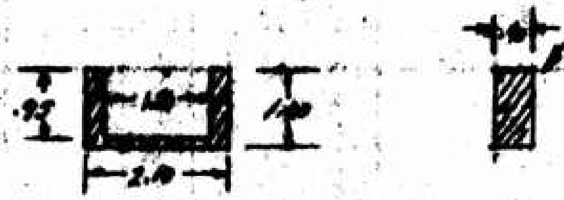


SHEAR ON SECT A-A

+1192
+2448
-1.7(257) = -437
= 3203 # ULT

$M_{AA} = (3203)(4.2) = 13,452$ IN # ULT

NEGLECT THIS PORTION AS EFFECTIVE



$I_{AA} = \frac{(1.00)(2.10)^3}{12} - \frac{(.95)(1.50)^3}{12}$

$I_{AA} = .5046$ IN^4

SECTION B-B

$f_b = \frac{Mc}{I} = \frac{(13,452)(1.05)}{.5046} = 27,980$ PSI ULT

$F_b = 43,500$ PSI (REF P 5.2.9.A.2)

$M.S. = \frac{43,500}{27,980} - 1 = \underline{.55}$

RIB - STA 33.25

CUTOUT DEPTH = 6.75 IN

$M_{AA} = 3203\left(\frac{6.75}{2}\right) = 10,810$ IN #

$I = \frac{(1.00)(1.30)^3 - (.95)(.81)^3}{12}$, .229 IN^4

$f_b = \frac{Mc}{I} = \frac{10810(.58)}{.229} = 27,370$

$M.S. = \frac{43,500}{27,370} - 1 = \underline{.59}$

INBOARD TORQUE BOX DROOP STOP COND

RIBS ANALYSIS - CONT'D

FORWARD BOX

MULTIPLY q_L BY $\frac{10180}{1000}$ = 10.18 (LOADS REF. PAGE 5.29.6.1)

MULTIPLY q_T BY $\frac{35,834}{7550}$ = 4.75

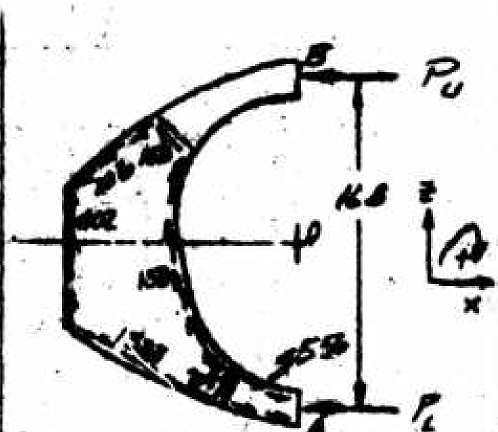
@ SECTION D-D q = (4.75)(84.7) = 402 #/IN ULT

@ SECTION BETWEEN C-C & D-D q = (4.75)(43.3) = 206 #/IN ULT

@ SECTION C-C q = (4.75)(33.3) = 158 #/IN ULT

IN LOWER SKIN q = $\frac{10180}{9.0}$ = 1131 #/IN ULT

SHEAR FLOW	X	Z	HORIZ FORCE	VERT FORCE	2A	M_0
206	4.20	5.50	-865	-721	[illegible]	-11,515
158 / 158	1.90	13.80	-300	+2044	81.1	+12,814
714	1.4	2.00	+1800	[illegible]	.24	-1713
1337	6.50	3.40	+8691	[illegible]	76.2	-101,879
402	0	8.4	0	+3216	100.8	+40522
556	4.3	1.20	+2391	-667	26.5	-14734
556	6.2	.90	+3447	-500	51.3	-29,523
Σ	—	—	+14364	[illegible]	—	-105,028



$\Sigma M_A = 0 = -16.8 P_U - 105,028 + 14364(8.4)$

P_U = 930 # ULT

$\Sigma M_B = 0 = 16.8 P_L - 105,028 - 14,364(8.4)$

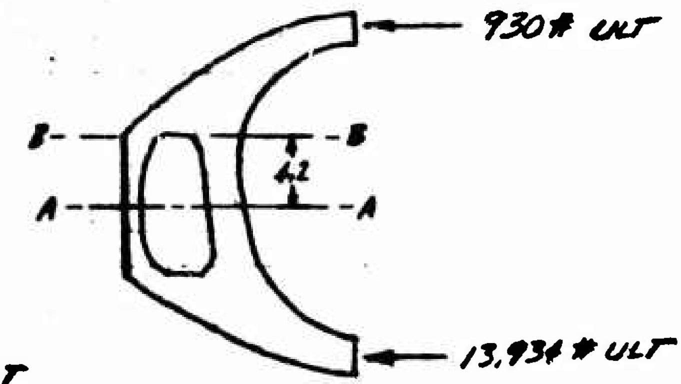
P_L = 13,934 # ULT

INBOARD TORQUE BOX   DROOP STOP COND

RIBS ANALYSIS - CONT'D

FORWARD BOX

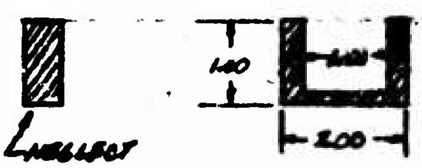
RIB-STA 24.25



SHEAR ON SECT A-A

$$-930\#$$
$$-865\#$$
$$1.5 \times 158 = -237\#$$
$$-2032\# \text{ ULT}$$

$$M = 2032(4.2) = 8534 \text{ "\# ULT}$$



$$I_{AA} = \frac{(1.00)(2.00)^3 - (.95)(1.50)^3}{12} = .3995 \text{ IN}^4$$

$$f_b = \frac{MZ}{I} = \frac{(8534)(1.00)}{.3995} = 21,360 \text{ PSI ULT}$$

$F_b = 43,500$ PSI (REF PG 5.2.9.8.2) $M.S. = \frac{43,500}{21360} - 1 = \underline{1.03}$

RIB STA 33.25

CUTOUT DEPTH = 6.75

$$M_{AA} = 2032\left(\frac{6.75}{2}\right) = 6858 \text{ "\# ULT}$$

$$I_{AA} = \frac{(1.00)(1.15)^3 - (.95)(.50)^3}{12} = .117 \text{ IN}^4$$

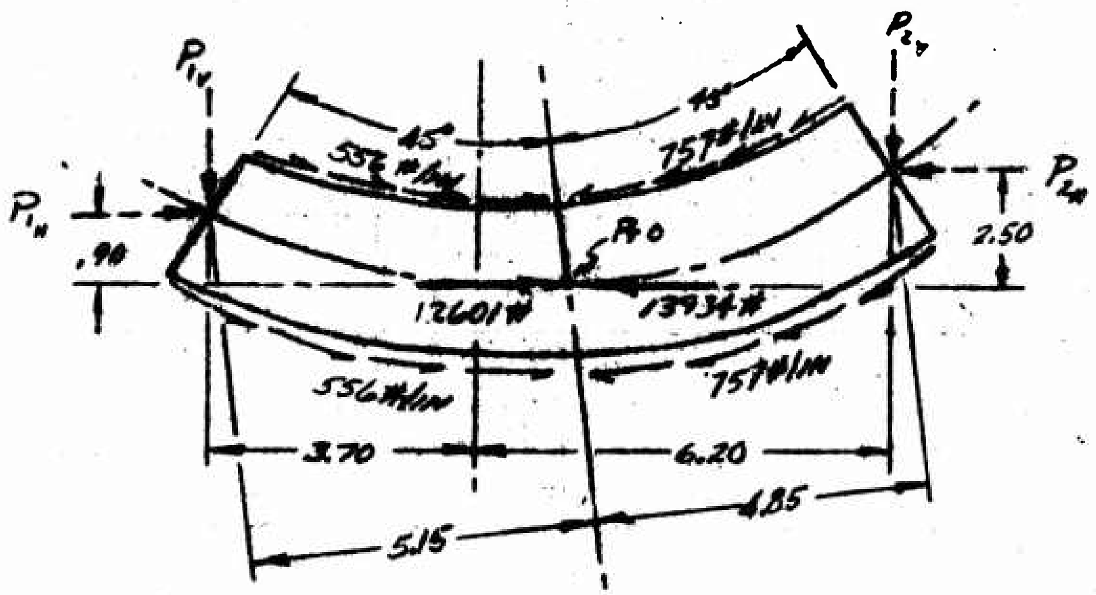
$$f_b = \frac{MZ}{I} = \frac{6858(.58)}{.117} = 33,995 \text{ PSI ULT}$$

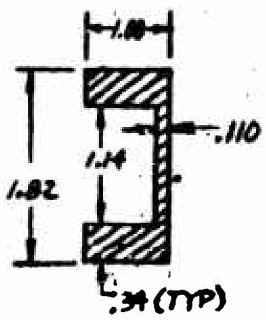
$$M.S. = \frac{43500}{33995} - 1 = \underline{.28}$$

INBOARD TORQUE BOX   DROOP STOP COND

RIBS ANALYSIS - CONT'D

SECONDARY BENDING, RIB LOWER PORTION





$$I_{NA} = \frac{(1.00)(1.82)^3 - (.89)(1.14)^3}{12}$$

$$I_{NA} = .397\ IN^4$$

$P_{1H} = 13934 - 556(5.15)(2) = 8208\#\ ULT$

$P_{2H} = 12601 - 757(4.85)(2) = 5258\#\ ULT$

$P_{1V} = (556)(3.60) = 2002\#\ ULT$

$P_{2V} = (757)(2.75) = 2082\#\ ULT$

$$\curvearrowleft \Sigma M_o = 0 = M_o + 8208(.90) + 2082(4.85) - 5258(2.50) - 2002(5.15)$$

$$M_o = 5790\#$$

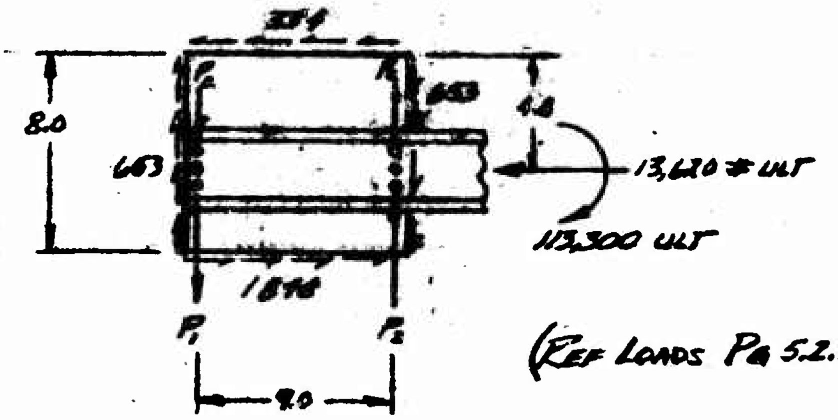
$$f_b = \frac{Mz}{I_{NA}} = \frac{(5790)(.91)}{.397} = 13{,}510\ PSI$$

$$M.S. = \frac{43500}{13510} - 1 = \underline{2.22}$$

INBOARD TORQUE BOX DROOP STOP COND.

5.2.9.9 SPARS ATTACHMENT

FREEBODY OF REAR WEB & REAR SPAR



(REF LOADS PG 5.2.9.6.1)

P_1 & P_2 ARE VERTICAL CAP LOADS REQ'D TO BRING THE FREEBODY INTO EQUILIBRIUM

$$P_c = \frac{113,300}{9.0} = 12,590 \text{ \# ULT}$$

$$P_1 = P_2 = \frac{113,300 - (334)(4)(6.0) - (1846)(9)(3.2) - (653)(8)(4.5)(2)}{9.0} = -207\# \approx 0$$

SPAR ATTACHMENT MAS 334 BOLTS (3)

$$P_{BOLT} = \frac{12,590}{3} = 4200 \text{ \# ULT}$$

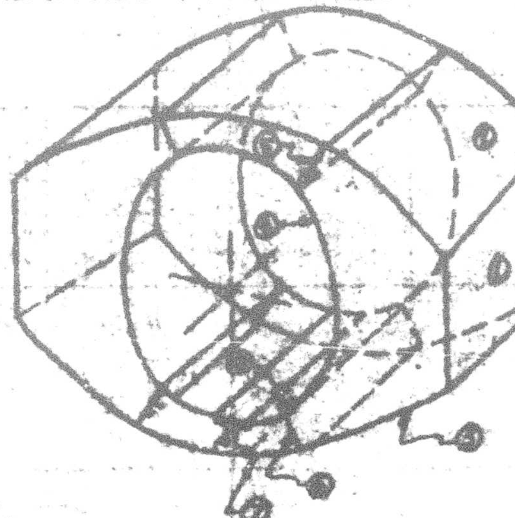
$P_{ALLOW} = 4650\#$ (REF 1) $\quad M.S. = \frac{4650}{4200} - 1 = \underline{.11}$

FWD SPAR OK BY COMPARISON OF LOADS

INBOARD TORQUE BOX DROOP STOP COND.

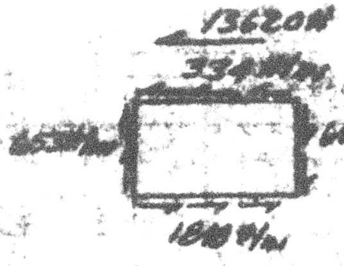
5.2.9.10 PANELS ANALYSIS

FOR THIS ANALYSIS EACH PANEL IS ASSUMED RECTANGULAR IN SHAPE. LOADS ARE OBTAINED FROM THE RIBS ANALYSIS. PANELS ARE PERMITTED TO BUCKLE.



REAR BOX

PANEL No 1 .063 2024T6 9.0 x 8.0



$f_s = \frac{1848}{.063} = 29{,}300$ PSI

LOWER SECTION OF PANEL ONLY IS CONSIDERED. 9.0 x 3.5 x .063

$\frac{b}{a} = \frac{3.5}{9.0} = .39$; $K = 5.7$

$F_{s_{cr}} = (5.7)(10.7 \times 10^6)\left(\frac{.063}{3.5}\right)^2 = 19{,}750$ PSI

$\frac{f_s}{F_{s_{cr}}} = \frac{29{,}300}{19{,}750} = 1.48$ $F_{sw} = 26{,}000$

(REF 3, FIG 15.16. PG 410)

INCREASE WEB t TO .072

$f_s = \frac{1848}{.072} = 25{,}650$ PSI

$F_{s_{cr}} = (5.7)(10.7 \times 10^6)\left(\frac{.072}{3.5}\right)^2 = 25{,}850$ PSI

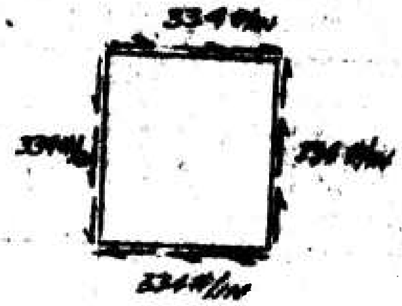
$\frac{f_s}{F_{s_{cr}}} = \frac{25{,}650}{25{,}850} = .993$, $F_{sw} = 27{,}000$ PSI $M.S. = \frac{27000}{25{,}650} - 1 = \underline{.05}$

INBOARD TORQUE BOX DROOP STOP COND.

PANELS ANALYSIS - CONT'D

REAR BOX

PANEL No 2 .051 2024 T6 9.0 x 9.0



$f_s = \frac{334}{.051} = 6550$ PSI

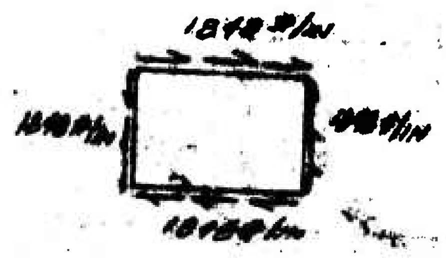
$AR = 1.0 \quad K = 10.8$

$F_{scr} = (10.8)(10.7 \times 10^6)\left(\frac{.051}{9.0}\right)^2 = 3710$ PSI

$\frac{f_s}{F_{scr}} = \frac{6550}{3710} = 1.77 \quad F_{sw} = 25,200$ PSI (REF 3, FIG 15.16)

M.S. HIGH +

PANEL No 3 .063 2024 T6 9.0 x 6.0 R = 23.8



$f_s = \frac{1848}{.063} = 29,330$ PSI

$AR = .67, \quad K = 7.5 \quad K_1 = 0.10$

$F_{scr} = (7.5)(10.7 \times 10^6)\left(\frac{.063}{6.0}\right)^2 + (.10)(10.7 \times 10^6)\left(\frac{.063}{23.8}\right) = 11,660$ PSI

$\frac{f_s}{F_{scr}} = \frac{29,330}{11,660} = 2.52 \quad F_{sw} = 23,400$ PSI

INCREASE t TO .081 $\quad f_s = \frac{1848}{.081} = 22,800$

$F_{scr} = (7.5)(10.7 \times 10^6)\left(\frac{.081}{6.0}\right)^2 + (.10)(10.7 \times 10^6)\left(\frac{.081}{23.8}\right) = 18,240$ PSI

$\frac{f_s}{F_{scr}} = \frac{22,800}{18,240} = 1.25 \quad F_{sw} = 27,000$ (REF 3, FIG 15.16)

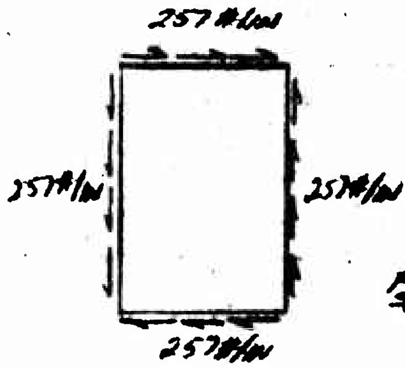
$M.S. = \frac{27,000}{22,800} - 1 = \underline{\underline{.18}}$

INBOARD TORQUE BOX — DROOP STOP COND.

PANELS ANALYSIS - CONT'D

REAR BOX

PANEL No. 4 — .051 2024 T6 9.0 X 17.8 $R \approx 6.8$



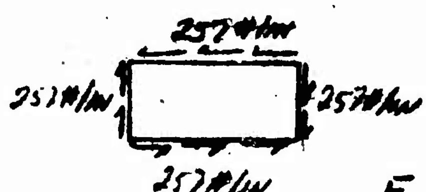
$f_s = \frac{257}{.051} = 5040$ PSI

$R = .70$; $K = 7.75$; $K_1 = 0.10$

$F_{s_{cr}} = (7.75)(10.7 \times 10^6)\left(\frac{.051}{9.0}\right)^2 + (.10)(10.7 \times 10^6)\left(\frac{.051}{6.8}\right) = 10610$ PSI

$\frac{f_s}{F_{s_{cr}}} = \frac{5040}{10{,}610} = .475$ $F_{su} = 27{,}000$ PSI (REF 3, FIG 15.10)   M.S. HIGH +

PANEL No 5 — .040 2024 T6 2.3 × 9.0



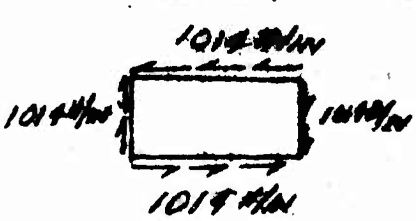
$f_s = \frac{257}{.040} = 6420$ PSI

$R = .256$, $K = 5.2$

$F_{s_{cr}} = (5.2)(10.7 \times 10^6)\left(\frac{.040}{2.3}\right)^2 = 168{,}600$ PSI OUT

$F_s = 37{,}000$ PSI   M.S. = HIGH +

PANEL No 6 — .051 2024 T6 2.9 × 9.0



$f_s = \frac{1014}{.051} = 19{,}900$ PSI

$F_s = 37{,}000$ PSI

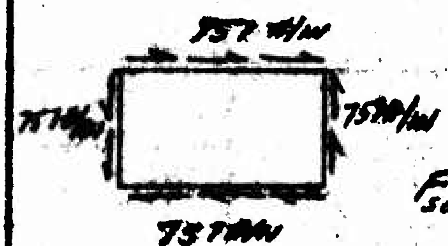
$M.S. = \frac{37{,}000}{19{,}900} - 1 = .86$

INBOARD TORQUE BOX — DROOP STOP COND.

PANELS ANALYSIS - CONT'D

REAR BOX

PANEL NO 7 — .063 2024-T6 9.0 × 6.0 R = 23.8



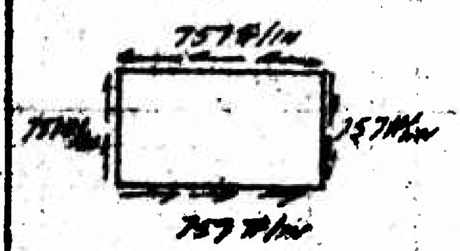
$f_s = \frac{757}{.063} = 12,000$ PSI

$AR = .67 \quad K = 7.5$

$F_{scr} = (7.5)(10.7 \times 10^6)\left(\frac{.063}{6.0}\right)^2 + (.10)(10.7 \times 10^6)\left(\frac{.063}{23.8}\right) = 11,660$ PSI

$\frac{f_s}{F_{scr}} = \frac{12,000}{11,660} = 1.03 \quad F_{sw} = 27,000$ (REF 3, FIG 15.16) $\quad M.S. = \frac{27,000}{12,000} - 1 = \underline{\underline{1.25}}$

PANEL NO 8 — .051 2024-T6 9.0 × 4.0 R = 6.1



$f_s = \frac{757}{.051} = 14,850$ PSI

$AR = .445 \quad K = 6.0$

$F_{scr} = (6.0)(10.7 \times 10^6)\left(\frac{.051}{4.0}\right)^2 + (.10)(10.7 \times 10^6)\left(\frac{.051}{6.1}\right) = 19420$

$\frac{f_s}{F_{scr}} = \frac{14850}{19420} = .765 \quad F_{sw} = 27,000 \quad M.S. = \frac{27000}{14850} - 1 = \underline{\underline{.82}}$

FORWARD BOX

PANELS 2, 4, 5, 6, 7 & 8 ARE OK BY COMPARISON WITH OPPOSITE IN REAR BOX.

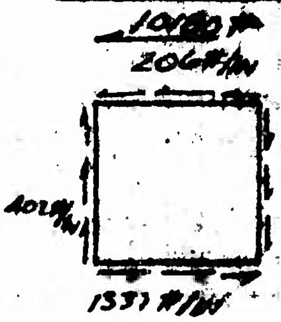
PANELS 1 & 3 WILL BE CHECKED.

INBOARD TORQUE BOX — DROOP STOP COND.

PANEL ANALYSIS - CONT'D

FORWARD BOX

PANEL No 1. — .063 2024T6 9.0×8.0



$f_s = \frac{1337}{.063} = 21{,}200$ PSI

LOWER SECTION OF PANEL CONSIDERED -

9.0 × 5.0 × .063

$R = \frac{3.5}{9.0} = .39 \quad K = 5.7$

$F_{s_{cr}} = 19{,}750$ PSI (FROM REAR BOX) N.G.

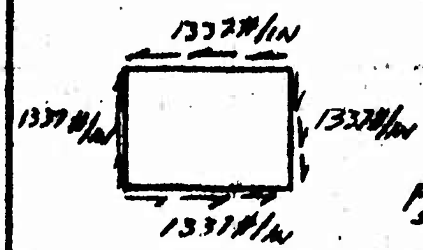
INCREASE WEB t TO .072

$f_s = \frac{1337}{.072} = 18{,}600$ PSI

$F_{s_{cr}} = (5.7)(10.7\times10^6)\left(\frac{.072}{3.5}\right)^2 = 25{,}800 \quad F_{s_{cr}} = 24{,}000$ PSI

$M.S. = \frac{24{,}000}{21{,}200} - 1 = \underline{\underline{.13}}$

PANEL No 3 — .063 2024T6 9.0×6.7



$f_s = \frac{1337}{.063} = 21{,}200$ PSI

$R = .745, \quad K = 8.15$

$F_{s_{cr}} = (8.15)(10.7\times10^6)\left(\frac{.063}{6.7}\right)^2 = 7705$ PSI

$\frac{f_s}{F_{s_{cr}}} = \frac{21{,}200}{7705} = 2.75, \quad F_{s_w} = 23{,}100$ PSI (REF 3, FIG 15.16)

$M.S. = \frac{23{,}100}{21{,}200} - 1 = \underline{\underline{.08}}$

9706

INBOARD TORQUE BOX DROOP STOP COND.

5.2.9.11 PANEL FASTENERS ANALYSIS

REAR BOX

PANEL No 1

▶ BETWEEN PANELS 1 & 2 9.0 IN (10) AD5 RIVETS

$q = 334$ #/IN

$P = 334 \times \frac{9.0}{10} = 301$ #/RIVET

$P_{ALLOW} = 596$ # (REF 1) $M.S. = \frac{596}{301} - 1 = \underline{.98}$

▶ BETWEEN PANELS 1 & 3 10 RIVETS AD6

$q = 1848$ #/IN

$P_{RIVET} = 1848 \times \frac{9.0}{10} = 1663$#

$P_{ALLOW} = 862$# USE 15 DD6 RIVETS

$P_{RIVET} = 1848 \times \frac{9.0}{15} = 1110$#

P_{ALLOW} (BEARING ON SHEET) = 1370# (REF 1) $M.S. = \frac{1180}{1110} - 1 = \underline{.06}$

P_{ALLOW} (SHEAR OF RIVET) = 1180#

▶ BETWEEN PANEL & RIB 33.25 (3) $\frac{3}{16}$ BOLTS, 2 AD5, 1 AD6 RIVET

$q = 653$ #/IN

$P_{TOTAL} = 653 \times 9.0 = 5877$#

$P_{ALLOW} = 3\left(\frac{9300}{2}\right) + 862 + 2(596)$ $\underline{M.S. = HIGH +}$

▶ RIB 24.25 CONNECTION OK BY COMPARISON

▶ SPAR CONNECTION 10 $\frac{3}{16}$ DIA LOCKBOLTS

$P_{TOTAL} = 13620$

$P_{BOLT} = 1362$# (CONSERVATIVELY)

$P_{ALLOW} = 2620$# (REF 1) $M.S. = \frac{2620}{1362} - 1 = \underline{.92}$

HUGHES TOOL COMPANY, AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE ... PREPARED BY: L. E. ... MODEL: ... REPORT NO. 285-13 PAGE 6.2.9.41

ROTOR BLADE

INBOARD TORQUE BOX — DROOP STOP COND.

PANEL FASTENERS - CONT'D

REAR BOX

PANEL NO 2

- BETWEEN PANELS 2 & 5 7 AD4 RIVETS IN 9 INCHES

$q = 334$ #/IN

$P_{RIVET} = 334 \times \frac{9}{7} = 430\#_{ULT}$ $P_{ALLOW} = 388\#$ (REF 1)

USE 7 AD5 RIVETS

$P_{ALLOW} = 596\#$ $M.S. = \frac{596}{430} - 1 = .39$

- BETWEEN PANEL & STA 22.25 RIB 7 AD5 RIVETS IN 9 INCHES

$q = 334$ #/IN

$P_{RIVET} = \frac{9}{7}(334) = 430\#$ ULT

$P_{ALLOW} = 596\#$ $M.S. = \frac{596}{430} - 1 = .39$

- PANEL TO STA 24.25 RIB OK BY COMPARISON

PANEL NO 3

- BETWEEN PANEL AND STA 33.25 RIB
(7) 3/16 DIA BOLTS IN 5.8 INCHES.

$q = 1848$ #/IN

$P_{BOLT} = \frac{5.8}{7}(1848) = 1530\#$ ULT

BEARING CRITICAL $P_{ALLOW} = 1550\#$ (REF 1)

$M.S. = \frac{1550}{1530} - 1 = .01$

- PANEL TO STA 24.25 RIB OK BY COMPARISON
- BETWEEN PANELS 3, 6 & 7 (7) AD6 RIVETS IN 9 INCHES

$P_{RIVET} = \frac{9}{7}(1848) = 2640\#$ $P_{ALLOW} = 862\#$

USE (8) 7/16 DIA BOLTS

$P_{BOLT} = \frac{9}{8}(1848) = 2310\#$ ULT

$P_{ALLOW} = 2620\#$ (REF 1) $M.S. = \frac{2620}{2310} - 1 = .13$

ROTOR BLADE

WEAKENED TORQUE BOX — DROOP STOP COND.

PANEL FASTENERS - CONT'D

REAR BOX

PANEL No 4

▶ BETWEEN PANELS 4 & 5 — 7 AD4 RIVETS

$\gamma = 257$ #/IN

$P_{RIVET} = 257 \times \frac{9}{7} = 367$#

$P_{ALLOW} = 388$# — $M.S. = \frac{388}{367} - 1 = \underline{\underline{.06}}$

▶ BETWEEN PANEL & RIBS, 13 AD5 RIVETS IN 12.8 INCHES

$\gamma = 257$ #/IN

$P_{RIVET} = 257 \times \frac{12.8}{13} = 253$#

$P_{ALLOW} = 596$# (REF 1) — $M.S. = \frac{596}{253} - 1 = \underline{\underline{1.36}}$

PANEL No 5

OK BY COMPARISON

PANEL No 6

▶ BETWEEN PANELS 6, 7 & 8, 9 AD6 RIVETS

$\gamma = 1014$ #/IN

$P_{TOTAL} = 1014 \times 9.0 = 9126$# — $P_{ALLOW} = 862$# N6

USE 7 DD6 RIVETS, 2 AD6 RIVETS

$P_{ALLOW} = (7)(1180) + (2)(862)$

$= 9984$# (REF 1) — $M.S. = \frac{9984}{9126} - 1 = \underline{\underline{.08}}$

▶ BETWEEN PANEL 6 & RIBS

$\gamma = 1014$ #/IN — 3 AD5 RIVETS

$P_{RIVET} = 1014 \times \frac{2.9}{3} = 981$#

USE 3 DD6 RIVETS

$P_{ALLOW} = 1180$# (REF 1) — $M.S. = \frac{1180}{981} - 1 = \underline{\underline{.20}}$

INBOARD TORQUE BOX — DROOP STOP COND.

PANEL FASTENERS - CONT'D

REAR BOX

PANEL No. 7

▶ BETWEEN PANEL & RIBS (6) AD6 RIVETS IN 5.3 IN

$q = 757\#/IN$

$P_{RIVET} = \left(\frac{5.3}{6}\right)(757) = 670\#\ ULT$

$P_{ALLOW} = 862\#$

$M.S. = \frac{862}{670} - 1 = \underline{\underline{.29}}$

▶ BETWEEN PANEL & -0176 FITTING (10) AD6 RIVETS IN 9 INCHES

$q = 757\#/IN$

$P_{RIVET} = \frac{9}{10}(757) = 682\#\ ULT$

$P_{ALLOW} = 862\#$ (REF 1)

$M.S. = \frac{862}{682} - 1 = \underline{\underline{.26}}$

PANEL No 8.

▶ BETWEEN PANEL & -0176 FITTING

SEE CALCULATIONS FOR PANEL No 7 ABOVE

▶ BETWEEN PANEL & RIBS -

▶ FASTENER SIZE & SPACING IS DETERMINED BY WEIGHTED FATIGUE CONDITION.

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE ROTOR — MODEL: 285 — REPORT NO. 285-13 — PAGE: 5.2.9.11.4

PREPARED BY: [illegible] 2-9-[illegible]

CHECKED BY:

ROTOR BLADE

INBOARD TORQUE BOX — DROOP STOP COND.

PANEL FASTENERS – CONT'D

FORWARD BOX

PANEL NO 1.

▶ BETWEEN PANELS 1 & 2 (7) AD6 RIVETS IN 9 INCHES

$q = 206$ #/IN

$P_{RIVET} = \frac{9}{7}(206) = 294$ # ULT

$P_{ALLOW} = 862$ # (REF 1)

$M.S. = \frac{862}{294} - 1 = 1.93$

▶ BETWEEN PANELS 1 & 3 (7) 3/16 BOLTS IN 9 INCHES

$q = 1337$ #/IN

$P_{BOLT} = 1337\left(\frac{9}{7}\right) = 1720$ # — $P_{ALLOW} = 1370$ # (BEARING) (REF 1)

USE (12) DD6 RIVETS

$P_{RIVET} = 1337\left(\frac{9}{12}\right) = 1005$ # ULT — $M.S. = \frac{1370}{1005} - 1 = .36$

▶ BETWEEN PANEL & STA 33.25 RIB

(3) AD5 RIVETS, (3) 1/4 DIA BOLTS, (1) 5/16 DIA BOLT

$q = 406$ #/IN

$P_{TOTAL} = 406 \times 9 = 3660$ # ULT

$P_{TOTAL\ ALLOW} = (3 \times 596) + (3 \times 4650) + (7300)$ (REF 1) — $M.S. = $ HIGH +

▶ PANEL TO STA 24.25 RIB OK BY COMPARISON

▶ SPAR CONNECTION OK BY COMPARISON TO REAR SPAR ANALYSIS.

PANEL NO 2

▶ BETWEEN PANELS 2 & 5 (7) AD6 RIVETS IN 9 INCHES

$q = 206$ #/IN OK BY COMPARISON TO REAR BOX

▶ BETWEEN PANEL & STA 33.25 RIB. (4) AD5, (3) AD4 RIVETS IN 5.0 INCHES. $q = 206$ #/IN OK BY COMPARISON

▶ PANEL TO 24.25 RIB (6) AD4, (1) AD5 RIVET

$q = 206$ #/IN OK BY COMPARISON TO REAR BOX

INBOARD TORQUE BOX DROOP STOP COND.

PANEL FASTENERS - CONT'D

FORWARD BOX

PANEL No 3

▶ BETWEEN PANEL & STA 33.25 RIB (1) 3/16 DIA BOLTS IN 7 INCHES

$q = 1337$ #/in

$P_{BOLT} = \frac{7}{7}(1337) = 1337$ # ULT

$P_{ALLOW} = 1550$ # (BEARING) (REF 1)   M.S. $= \frac{1550}{1337} - 1 = .16$

PANEL No 4

OK BY COMPARISON TO REAR BOX

PANEL No 5

OK BY CALCULATIONS ABOVE

PANEL No 6

▶ BETWEEN PANELS 6, 4 & 8 (7) AD6 RIVETS IN 9 INCHES

$q = 714$ #/in $P_{RIVET} = 714$ # ULT

$P_{ALLOW} = 862$ # (REF 1)   M.S. $= \frac{862}{714} - 1 = .21$

▶ BETWEEN PANEL & RIBS (3) AD5 RIVETS IN 2.5 INCHES

$q = 714$ #/in

$P_{RIVET} = \frac{2.5}{3}(714) = 596$ # ULT

$P_{ALLOW} = 596$ # (REF 1)   M.S. $= \frac{596}{596} - 1 = 0$

PANEL No 7

OK BY COMPARISON TO REAR BOX

PANEL No 8

OK BY COMPARISON TO REAR BOX

INBOARD TORQUE BOX DROOP STOP COND

5.2.9.12 285-0176 FITTING

MAT'L - AL. ALLOY 2024-T4

FASTENER ATTACHMENTS OK BY PANEL ANALYSIS
CHECK FOR COMPRESSION -

$A = (1.62)(2)(.13) + (1.83 - .26)(.13) = .625 \, IN^2$

$P = 23{,}800 \# \text{ ULT}$

$f_c = \frac{23{,}800}{.625} = 38000 \text{ PSI ULT}$

$F_{cu} = 43{,}500 \text{ PSI}$ (REF PG 5.2.9.8.2)

$M.S. = \frac{43500}{38000} - 1 = \underline{\underline{.16}}$

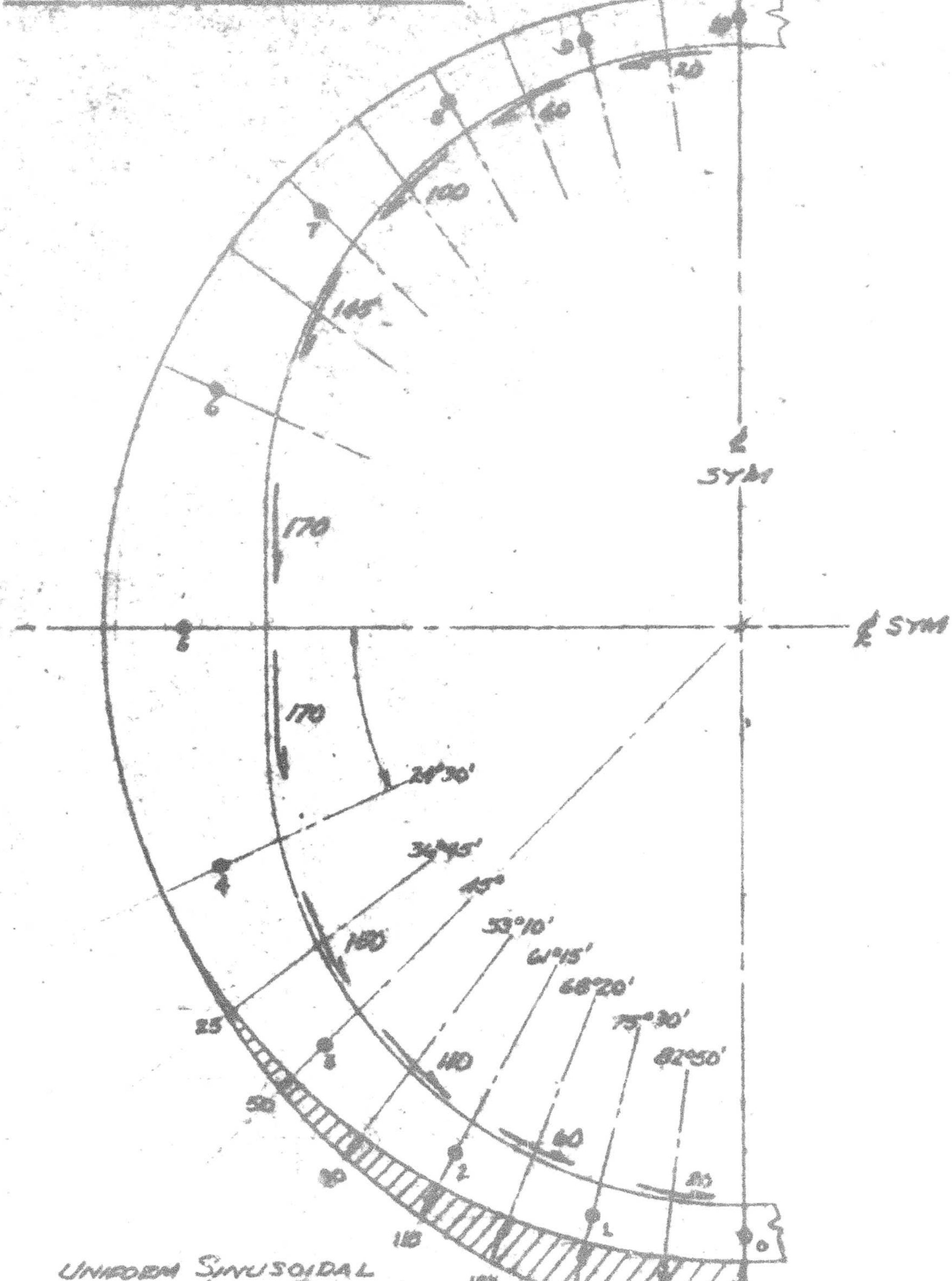
PREPARED BY: [illegible] 2-13-[illegible]

CHECKED BY:

ROTOR BLADE

5.2.9.15 285-0126 BALL - HOT CYCLE ROTOR FEATHERING BEARING

MAT'L - ALUM. CSTG. 356-T6



UNIFORM SINUSOIDAL BEARING LOAD DISTRIB.

UNIT LOAD = 1626 #

HUGHES TOOL COMPANY - AIRCRAFT DIVISION

ANALYSIS: Hot Cycle Rotor | MODEL 285 | REPORT NO. 285-12 | 5.2.9.121

PREPARED BY: L.L. [illegible] 2-13-60

CHECKED BY:

Rotor Blade

Flatwise Bending (285-0126) Moments Due To Bending Distribution

STA	ΔM_{160}	ΔM_{140}	ΔM_{125}	$\Delta M_{[illegible]}$	ΔM_{115}	ΔM_{80}	$\Delta M_{[illegible]}$	ΔM_{25}	ΣM_1	
0	0									
1	195	190							385	
2	372	542	336	144					1394	
3	536	885	676	453	230	87			2867	
4	669	1188	998	[illegible]	504	280	129	39	4567	
5	712	1350	1208	948	722	458	252	106	5806	
6	669	1340	1269	1100	843	575	343	161	6300	
7	536	1143	1144	1050	833	595	376	187	5863	
8	372	874	940	915	756	560	370	192	4979	
9	195	550	673	710	619	482	332	179	3740	
10	0	209	370	465	445	376	276	157	2298	

HUGHES TOOL COMPANY - AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE [illegible] MODEL: 285 REPORT NO. 285-13 PAGE 5.2.9.13.2

PREPARED BY: L.L. [illegible] 2-13-63

CHECKED BY:

ROTOR BLADE

FEATHERING BEARING (285-0172) MOMENTS DUE TO DIST. SHEAR

[illegible]	ΔM_{20}	ΔM_{60}	$\Delta M_{[illegible]}$	$\Delta M_{[illegible]}$	ΔM_{130}	ΔM_{170}	ΔM_{105}	$\Delta M_{[illegible]}$	ΔM_{60}	ΔM_{20}	ΣM_z
0	0										0
1	-9	0									-9
2	+3	-21	0								-18
3	24	9	-61	0							-28
4	66	97	17	-105	0						75
5	124	250	217	23	-179	0					435
6	185	423	484	372	107	-104	0				1367
7	235	584	766	600	136	134	-58	0			2397
8	269	704	1000	911	408	408	61	-40	0		3721
9	290	792	1205	1209	714	714	247	25	-15	0	5181
10	304	850	1375	1429	1037	1037	479	126	19	-6	6704

FORM 3703

[illegible] TOOL COMPANY - AIRCRAFT DIVISION

[illegible] [illegible] — MODEL 285 — REPORT NO. 285-13

PREPARED BY: T. L. [illegible] 2-13-[illegible]

CHECKED BY:

ROTOR BLADE

[illegible] [illegible] (285[illegible]) ENERGY SOLUTION FOR [illegible] BENDING

STA	[illegible]	m_1	m_2	$f\left(\frac{I}{I}\right)$	Δ	$\frac{M m_1}{I}$	$\frac{M m_2}{I}$	$\frac{m_1 m_2}{I}$	$\frac{m_1^2}{I}$	$\frac{m_2^2}{I}$
0	0	-1.0	0	1.0		0	0	0		0
					1.96					
1	276		-.25	.85		-312	-72	.20		.04
					1.96					
2	1376		-1.06	.67		-982	-970	.70		.74
					2.18					
3	2839		-2.45	.50		-1410	-3480	1.23		3.01
					2.66					
4	4642		-4.75	.33		-1530	-7240	1.57		7.45
					3.07					
5	6241		-7.82	.25		-1600	-12100	1.95		15.30
					3.07					
6	7667		-10.85	.33		-2530	-27460	3.58		38.86
					2.66					
7	8260		-13.14	.50		-4130	-54250	6.57		86.30
					2.18					
8	8700		-14.58	.67		-5830	-85000	9.76		142.30
					1.96					
9	8921		-15.39	.83		-7400	-114000	12.77		196.30
					1.96					
10	9007	-1.0	-15.64	1.0		-9007	-140000	15.64		244.60
					Σ	-48216	-818610	10243	13.12	1319.63

$13.12K_1 + 102.43K_2 = 48216$

$102.43K_1 + 1319.63K_2 = 818610$

$-1[illegible]K_1 - 1319.63K_2 = -878843$

$66.60K_1 = 60233$

$K_1 = 904.4$

$K_2 = 538.13$

FORM [illegible]

ROTOR BLADE

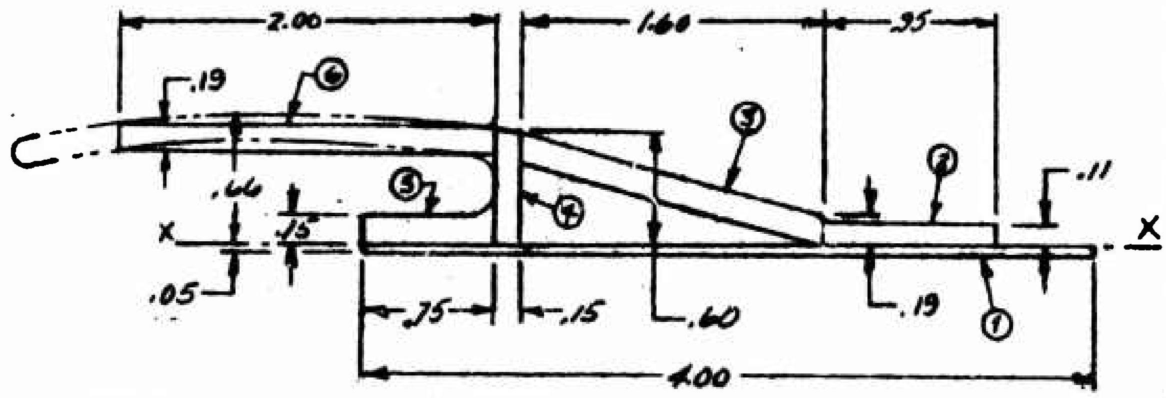
FEATHERING BEARING (285-0126) ENERGY SOLUTION FOR RING BENDING (CONT'D)

STA	M	M_1	M_2		TOTAL MOMENT	*
0	0	-904	0		-904	
1	376		-127		-655	
2	1376		-578		-106	
3	2839		-1348		587	
4	4642		-2613		1125	
5	6241		-4302		1035	
6	7667		-5969		794	
7	8260		-7229		127	
8	8700		-8021		-225	
9	8921		-8467		-450	
10	9007	-904	-8604		-501	

* FOR UNIFORM RING SINUSOIDAL BEARING DISTRIBUTION:

$$M = (.0435)(1626)(7.8) = 550 \text{ IN-\#}$$

FEATHERING BEARING - CONT'D



ITEM	AREA	$\bar{y}$	$A\bar{y}$	I_{xx}
1	.2000	-.025	-.0050	.0002
2	.1045	.055	.0058	.0004
3	.3040	.300	.0912	.0329
4	.0900	.300	.0270	.0108
5	.1125	.075	.0084	.0008
6	.4000	.550	.2200	.1224
Σ	1.2110	—	.3474	.1675

$\bar{y} = \frac{.3474}{1.2110} = .287\ IN$; $I_{NA} = .1675 - (1.211)(.287)^2 = .0677\ IN^4$

WEIGHTED FATIGUE COND.

$P = \pm 1732\#$ LIMIT (REF TABLE 5.4.2.2-2)

$P_{UNIT} = 1626\#$ (REF PG 5.2.9.13.0)

$M_{MEAN}\ \frac{1732}{1626}\left(\frac{904}{2}\right) = 482''\#$ LIM (LOAD REF PG 5.2.9.13.4)

$P_{AXIAL} = \frac{1732}{1626}(550) = \pm 586\#$ LIM

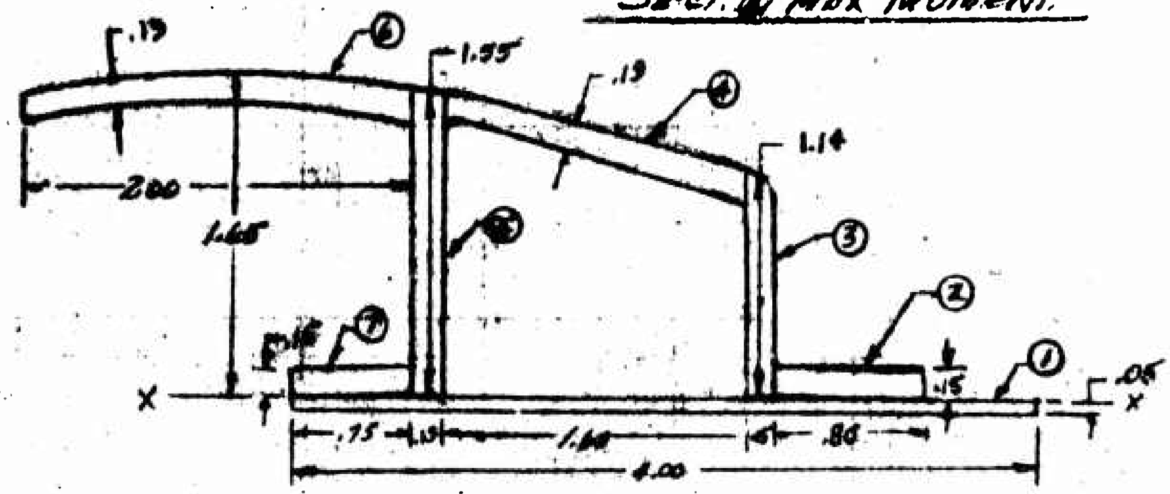
$f_b = \frac{482(.660-.287)}{.0677} = 2660$ PSI LIM (COMP)

$f_t = \frac{482(.287)}{.0677} - \frac{\pm 586}{1.211} = \pm 1566$ PSI LIM

$F_a = \pm 7500$ PSI FOR $K_t = 3.0$ $M.S. = \frac{2500}{1566} - 1 = .60$

FEATHERING BEARING - CONT'D

SECT. @ MAX MOMENT



ITEM	A	Y	AY	I_{xx}
1	.2000	-.025	-.0050	.0002
2	.1200	.075	.0090	.0009
3	.1710	.570	.0975	.0741
4	.3040	1.23	.3739	.3951
5	.2325	.775	.1802	.1862
6	.4000	1.54	.6160	.9500
7	.1125	.075	.0084	.0008
Σ	1.5400	—	1.2800	1.6073

$\bar{Y} = \frac{1.2800}{1.5400} = .831\,IN$

$I_{NA} = I_{xx} - A\bar{Y}^2$

$= 1.6073 - (1.54)(.831)^2$

$= .5438\ IN^4$

WEIGHTED FATIGUE COND

$M_{MEAN} = \left(\frac{1732}{1626}\right)\left(\frac{1125}{2}\right) = 600\,"\#$ (LOAD REF PG 5.2.9.13.4)

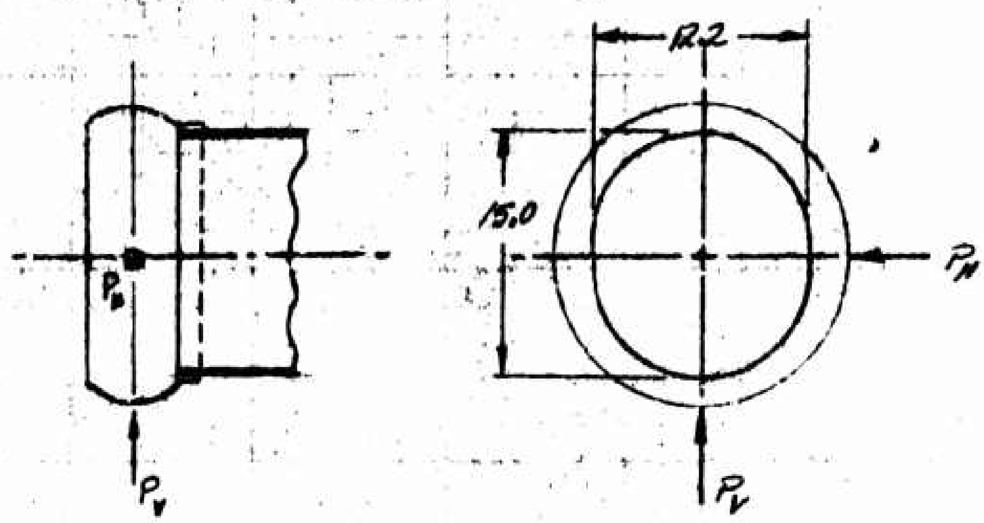
$f_t = \frac{(600)(.83)}{.544} = 915\ PSI$ LIM

HUGHES TOOL COMPANY AIRCRAFT DIVISION

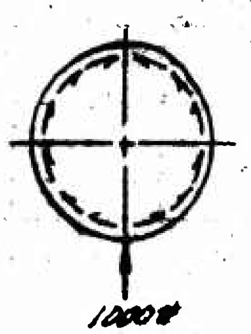
[illegible] 265-13

ROTOR BLADE

[illegible] - CONT'D

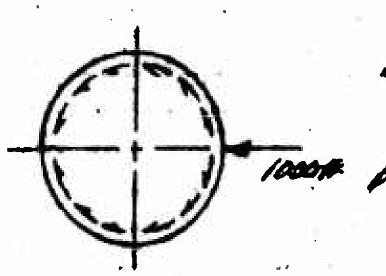


LOADING CONDITIONS AND UNIT LOAD SOLUTION -



CONDITION 1 -

$$q^1_{AVG} = \frac{V}{\pi R + 2h} = \frac{1000}{(\pi)(6.1) + 2([illegible])} = 40.4 \ \#/IN$$



CONDITION 2

$$q^2_{AVG} = \frac{V}{\pi R} = \frac{1000}{\pi(6.1)} = 52.1 \ \#/IN$$

$$q_{MAX} = q^1_{AVG} + q^2_{AVG} = \frac{P_V}{1000}(40.4) + \frac{P_H}{1000}(52.1)$$

9704

FEATHERING BEARING ATTACHMENT

WEIGHTED FATIGUE COND

$P_V = 2551$ # LIM (MAX)

$P_H = \pm 243$ # LIM

$q_{MAX} = 2.551(40.4) + .243(52.1) = 116$ #/IN

$q_{MEAN} = 53$ #/IN

TUBE CIRCUMFERENCE = 44.33 IN

78 AD5 RIVETS IN JOINT PATTERN

$$f_{br} = \left(\frac{44.33}{78}\right)\left(\frac{53}{.051 \times .156}\right) = 3760 \text{ psi}$$

$F_{br} = 7650$ # (REF PG 5.2.9.4.0)

$$M.S. = \frac{7650}{3760} - 1 = \underline{1.03}$$

2½ G MANEUVER CONDITION

$P_V = 6500$ # ULT

$P_H = 1200$ # ULT

$q_{MAX} = 6.5(40.4) + 1.2(52.1) = 324$ #/IN

$$P_{RIVET} = \left(\frac{44.33}{78}\right)(324) = 184\#$$

$P_{ALLOW} = 596$ # (REF 1)

$$M.S. = \frac{596}{184} - 1 = \underline{2.24}$$

5.2.10 Blade Ducts

The primary purpose of the duct is to transfer the hot gases at elevated pressures from the engine to the tip cascade. The duct is an integral part of the blade in the blade constant section outboard of Station 90 and is separate from the blade from Station 15 to Station 90.

The duct from the hub to the blade constant section at Station 90 is supported at Stations 15.5, 42.5 and 88 with a centrifugal force tie for the outboard duct section at Station 81.7. The inboard duct support at Station 15.5 is designed such that the duct will cone with the blade and that the centrifugal force loads, normal and chordwise shears may be transferred to the hub upper duct.

The duct inboard section is from Station 15.5 to Station 42. The primary loads are centrifugal force load of the inboard duct section and duct internal pressure loads. There is also a cyclic load due to the relative movement of the inboard duct and the main rotor blade section. The elevated temperature of the structure varies from 500°F for the duct gimbal ring to 1050°F for the basic duct section.

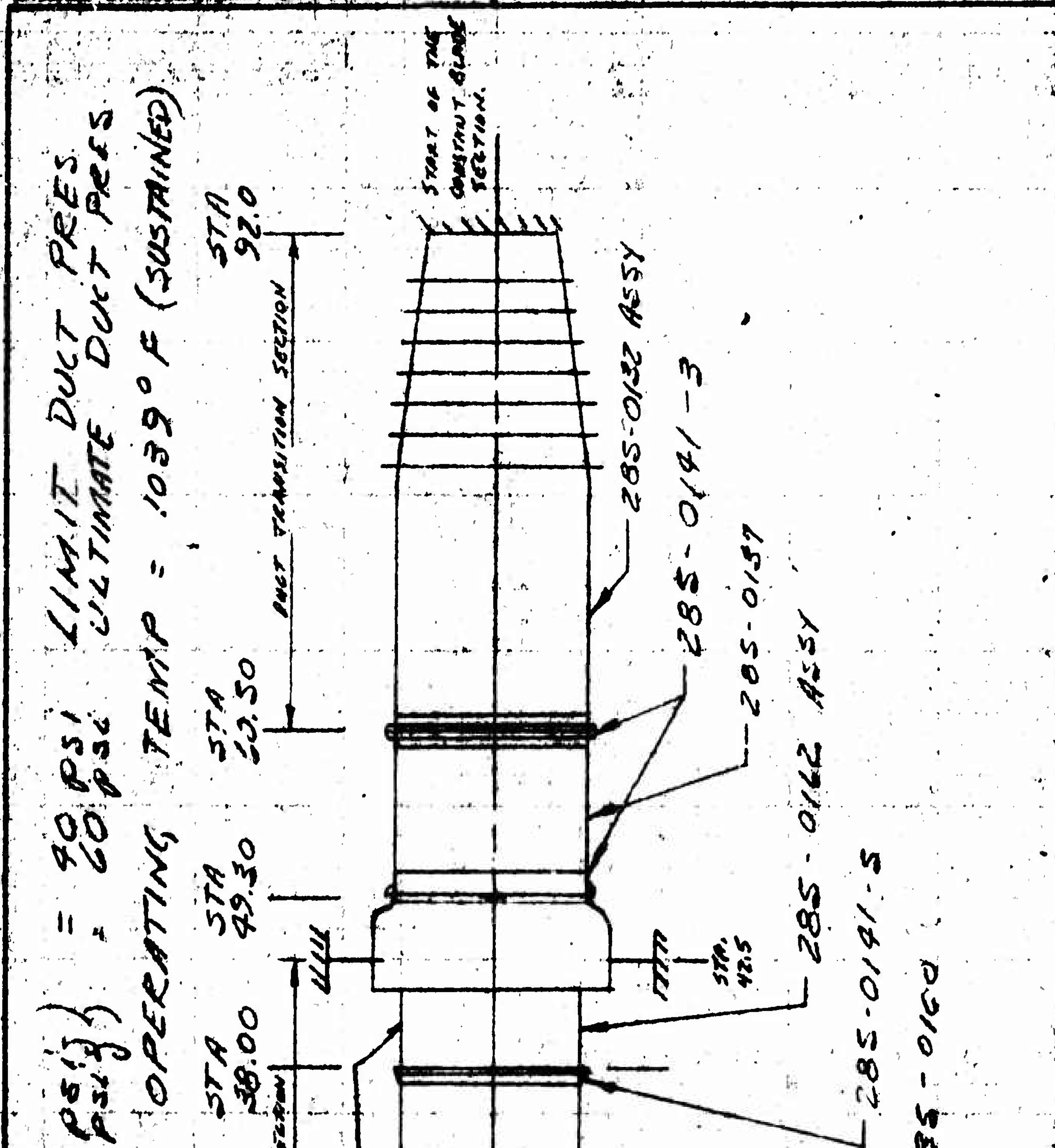
The center duct support at Station 42 is designed with a sliding pressure seal so that the inboard and outboard duct sections may move spanwise and rotate independent of each other. These relative movements are required to absorb thermal expansion, hub tilt and blade coning and feathering. The support at Station 42 is designed to react normal and chordwise loads but offer no resistance to torque.

The outboard support at Station 88 is in the form of a flexure. The flexure is capable of transferring normal and chordwise loads and torque. It is flexible in attempting to resist bending moments or centrifugal force loads. A load tie is added at Station 81.7 to react the centrifugal force load of the outboard duct section. The load tie is an adjustable strap tying the outboard duct to the rib and strap-spar fitting at Station 73 and is designed to carry only centrifugal force loads.

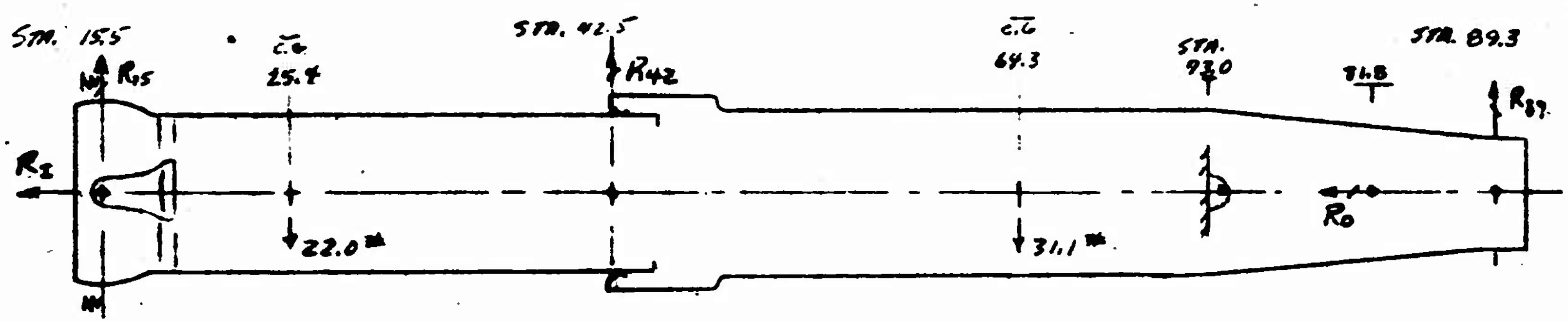
HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS: HOT CYCLE
PREPARED BY: W.L. ZIRRES 2-15-60
CHECKED BY:
MODEL: 285
REPORT NO. 285-13
PAGE 5.2.10.2

BLADE DUCT



DUCT SUPPORT REACTIONS



$$R_{15} = \frac{22.0(42.5-25.4)}{27.0} = 14.0^{\#} \qquad R_{42_I} = 22.0 - 14.0 = 8.0^{\#}$$

$$R_{89} = \frac{31.1\,(64.3-42.5)}{46.8} = 14.6^{\#} \qquad R_{42_O} = 31.1 - 14.6 = 16.5^{\#}$$

$$R_{42} = 7.4 + 16.5 = 23.9^{\#}$$

REACTIONS FOR UNIT WEIGHTS

$R_{15} = .633\ W_I$

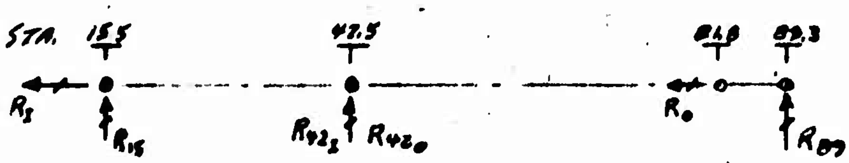
$R_{42} = .367\ W_I + .534\ W_O$

$R_{89} = .466\ W_O$

BLADE DUCT

INB'D DUCT

SUMMARY OF DUCT REACTIONS FOR CENTRIFUGAL FORCE AND INTERNAL PRESSURE LOADS. LOADS ARE LIMIT.



COND.	REACTION LOADING		R_s	R_{15}	R_{42_s}	R_{42_0}	R_0	R_{89}
WEIGHTED FATIGUE COND.	C.F.	STEADY	870	62	36	178	3270	156
		CYCLIC	± 5	± 30	± 18	2	5	2
	PRES.	STEADY	583	197	—	—		—
		CYCLIC	± 10	± 95	± 75	—	—	—
	SUM	STEADY	1453	259	36	178	3270	156
		CYCLIC	± 15	± 125	± 54	2	5	2
2½ g MANEUVER COND.	C.F.	STEADY	865	117				
		CYCLIC	± 13	55				
	PRES.	STEADY	598	266				
		CYCLIC	± 27	175				
	SUM	MAXIMUM	1403	613	99.	342	3240	299
		—						
OVER-REV. COND.	C.F.	STEADY	1452				5190	
		CYCLIC	-					
	PRES.	STEADY	569					
		CYCLIC	-					
	SUM	MAXIMUM	2021				5190	
		—						

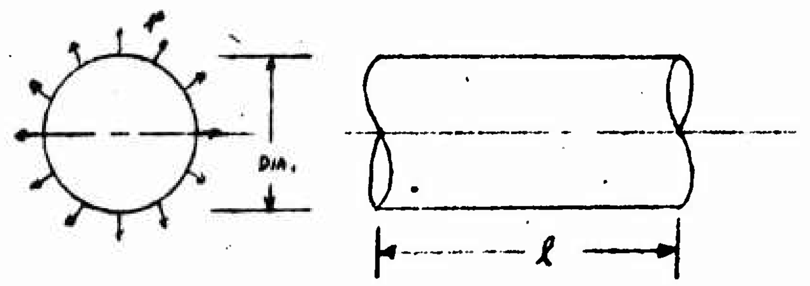
DUCT INTERNAL PRESSURES - LIMIT VALUES

DUCT PRESSURE IN COMBINATION WITH OTHER LOADS
BURSTING PRESSURE = 30. PSI

DUCT PRESSURE ACTING ALONE
BURSTING PRESSURE = 40. PSI
COLLAPSING " = -4.0 PSI

INBOARD DUCT

STA. 15.5 TO STA. 38 REF: DWG. 285-0179



HOOP TENSION STRESSES

ULT. BURSTING PRESSURE = 40 × 1.5 = 60 psi

DIA. = 8.55 DIA. $t_{MIN} = .012$

$f_t = \frac{60(4.275)}{.012} = 21400$ psi $\quad F_{TU} = 42000$ psi @ 1100°F

$M.S. = \frac{42000}{21400} - 1 = \underline{.96}$

FOR CONTINUOUS OPERATION $p = 23.6$ psi @ 1039°F

$f_t = \frac{23.6(4.275)}{.012} = 8400$ psi LIM.

CREEP YIELD @ 1039°F $F_{TY_c} = 12000$ psi

$M.S. = \frac{12000}{8450} - 1 = \underline{.42}$

COLLAPSING PRESSURE STRESSES

ALLOW. COLLAPSING PRES. $= P_{COL} = \frac{.807 E t^2}{\ell r}\left[\left(\frac{1}{(1-\mu^2)}\right)^3\left(\frac{t}{r}\right)^2\right]^{1/4}$

FOR INBOARD SECTION $t = .012$ $\ell = 6.67$ $r = 4.28$ $E = 24.4 \times 10^6$ @ 800°F

$P_{COL} = \frac{.807 \times 24.4 \times 10^6 (.012)^2}{6.67 \times 4.28}\left[\left(\frac{1}{.91}\right)^3\left(\frac{.012}{4.28}\right)^2\right]^{1/4} = 5.64$ psi @ 800°F

FOR CENTER SECTION $t = .016$ $\ell = 12.0$ $r = 4.28$ $E = 24.4 \times 10^6$ @ 800°F

$P_{COL} = \frac{.807 \times 24.4 \times 10^6 (.016)^2}{12.0 \times 4.28}\left[\left(\frac{1}{.91}\right)^3\left(\frac{.016}{4.28}\right)^2\right]^{1/4} = 6.50$ psi @ 800°F

MAX. COLLAPSING PRES. = −4.0 psi @ 800°F REF. SECT 1.

$M.S. = \frac{5.64}{4.00} - 1 = \underline{.41}$

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS HOT CYCLE MODEL 285 REPORT NO. 285-13 PAGE 5.2.146

PREPARED BY W.L. ZIBBERS 8-12-60

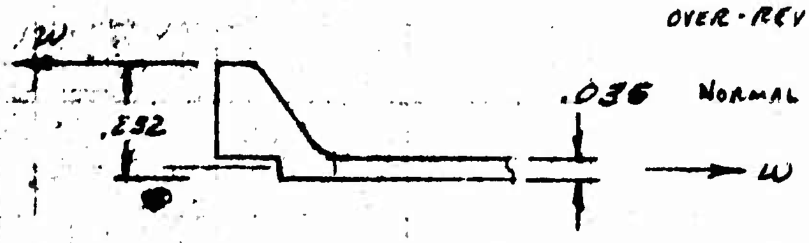
CHECKED BY

BLADE DUCT

285-0136 RING

CHECK RING END (CLAMP) STA 25.5

WEIGHT & C.G. OF DUCT OUTB'D OF CLAMP = 5.20# WITH C.G. @ STA. 38.0



OVER-REV COND. $w = \frac{5.20(112)}{8.55\pi} = 19.7$ #/IN. LIM

NORMAL COND. $w = \frac{5.20(68)}{8.55\pi} = 13.2$ #/IN. LIM

$M = .232\,(19.7) = 4.52$ "# (LIMIT)

$f_b = \frac{6M}{t^2} = \frac{(6)(4.53)}{(.045)^2} = 13600$ psi (LIM)

F_t yield $= 28000(1.5) = 42000$ psi (ULT)

1100° (SHORT TIME) REF. ⑤

$M.S. = \frac{42000}{13600(1.5)} - 1 = 1.06$

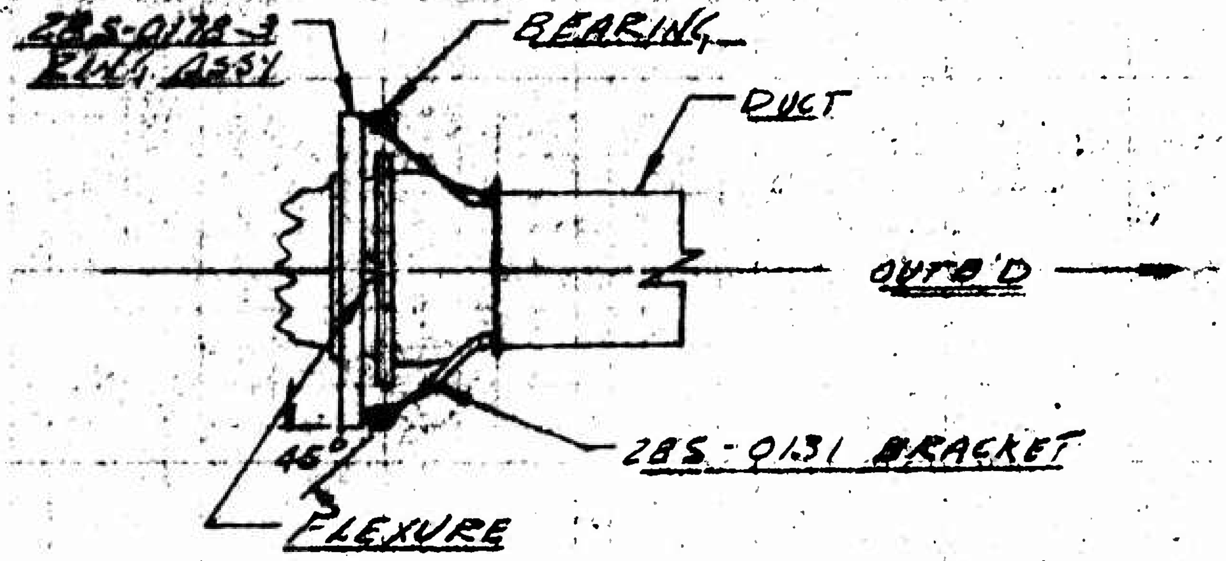
$M = (.232)(13.2) = 3.06$ "# (Lim)

$f_b = \frac{6M}{t^2} = \frac{6\,(3.06)}{(.045)^2} = 9{,}100$ psi (Lim)

$F_t = 12000$ psi (STRESS FOR C.R. OF .0001%/Hr, 1100° REF. ⑤

$M.S. = \frac{12000}{9100} - 1 = .32$

285-0160 DUCT ASSY



INTRODUCTION

THE 285-0131 BRACKET TRANSFERS THE DUCT LOADS (CENTRIFUGAL FORCE) TO THE FIXED STRUCTURE THROUGH THE END BEARINGS. THE BRACKETS MUST ALSO TRANSFER THE LOADS IMPOSED BY THERMAL EXPANSION OF THE DUCT.

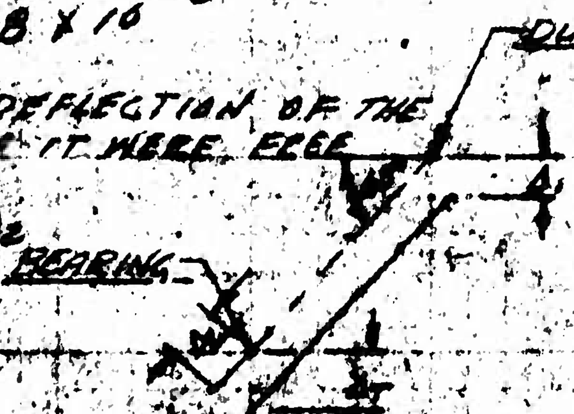
DUCT TEMP = 1050° F
BRACKET TEMP = 800° F

$\alpha_{SS} = 9.2 \times 10^{-6}$

$\alpha_{S} = 8 \times 10^{-6}$

Δ_T = TOTAL DEFLECTION OF THE BEARING IF IT WERE FREE TO MOVE

$\Delta_T = \Delta_1 + \Delta_2$



Δ_1 = DUCT
Δ_2 = BRACKET

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS ARTICULATED DUCT MODEL 285 REPORT NO. 285-13 PAGE 5.2.10.8

PREPARED BY W.L. KIBBES 7-28-52 BLADE DUCT

CHECKED BY

285-0180 DUCT ASSY

DUCT

$$\Delta_1 = 9.9\times10^{-6}(1050)\tfrac{1}{2}(8.6) = 4.32\times10^{-2}\ IN$$

BRACKET

$$\Delta_2 = 8\times10^{-6}(800)(5) = 2.56\times10^{-2}\ IN$$

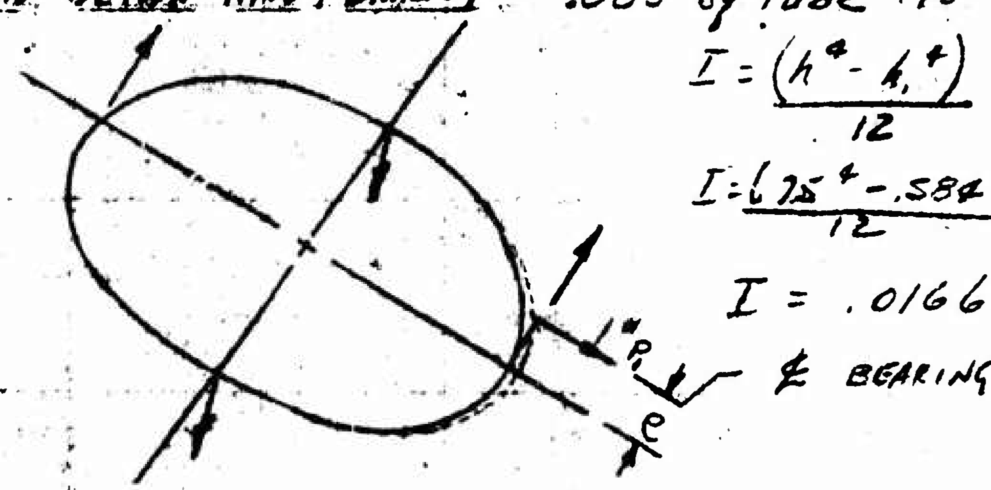
$$\therefore\ \Delta_T = [4.32 + .707(2.56)]\times10^{-2} = 6.88\times10^{-2}\ IN$$

Δ_3 OUTBD RING ASSUME TEMP = 475°F

$$\Delta_3 = 7.2\times10^{-6}(475)\tfrac{1}{2}(14) = 2.39\times10^{-2}\ IN$$

ADJUSTED $\Delta = [6.88-2.39]\times10^{-2} = \underline{.045\ IN.}$

PRELOAD BETW'N RING & BRACKET .083 sq tube .75



$$I = \frac{(h^4 - h_1^4)}{12}$$

$$I = \frac{(.75^4 - .584^4)}{12}$$

$$I = .0166\ IN^4$$

(RING) $\Delta_R = \dfrac{C_N\,R\,\ell^3}{EI} = \dfrac{.042\,(P_1)\,(6.5)^3}{30\times10^6 \times .0166}\ 10 = \underline{.0014 P_1 \times 10^{-2}}$

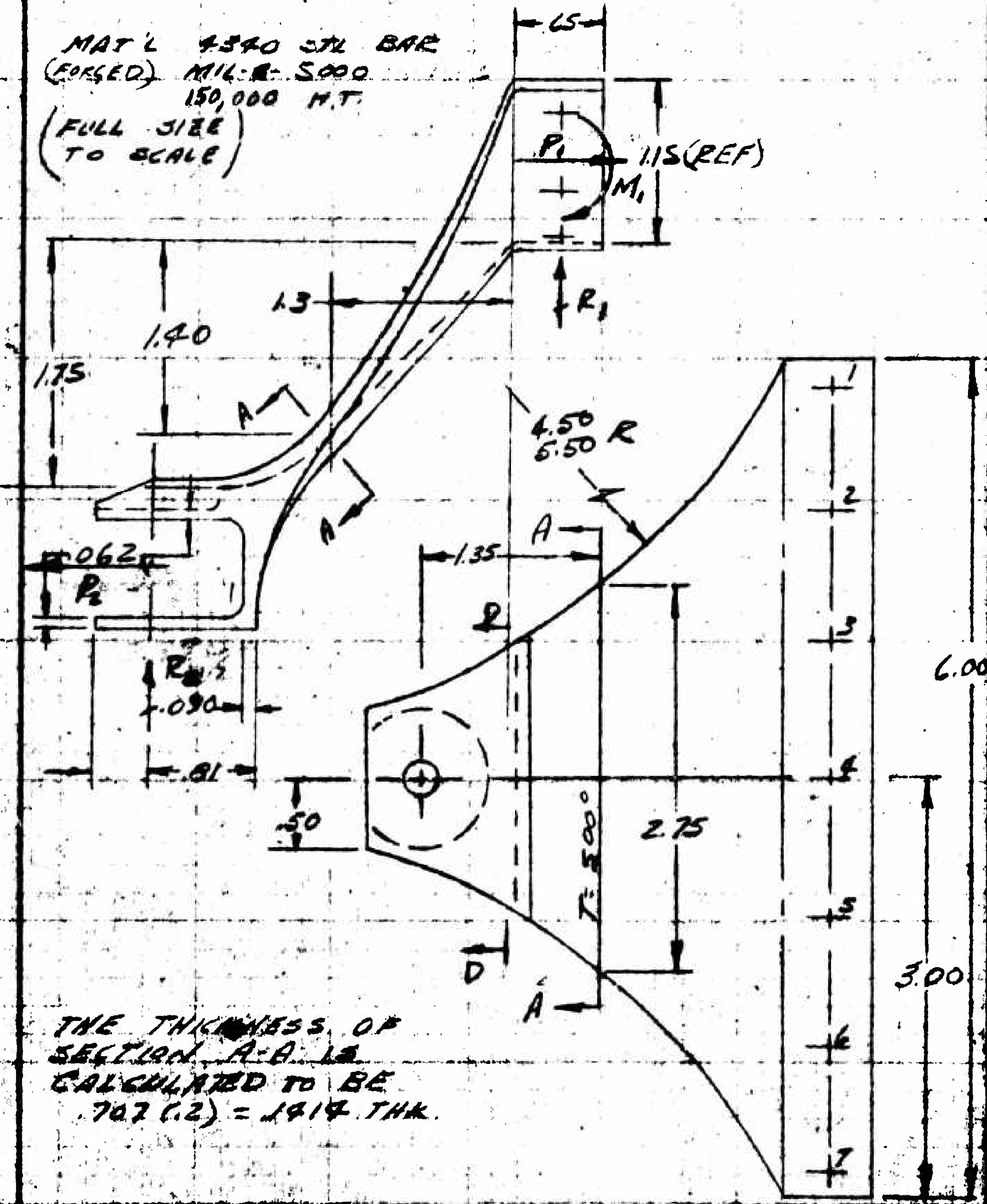
(BRACKET) $\Delta_B = \dfrac{P_1\ell^3}{3EI} = \dfrac{(P_1)(\ell)^3}{3\times30\times10^6 \times .00065} = \underline{.0137 P_1 \times10^{-2}}$

$$P_1 = \frac{.045}{(.0014 + .0137)10^{-2}} = \underline{298\#}$$

*I BE MODIFIED FOR THE I OF THE MIN SECTION

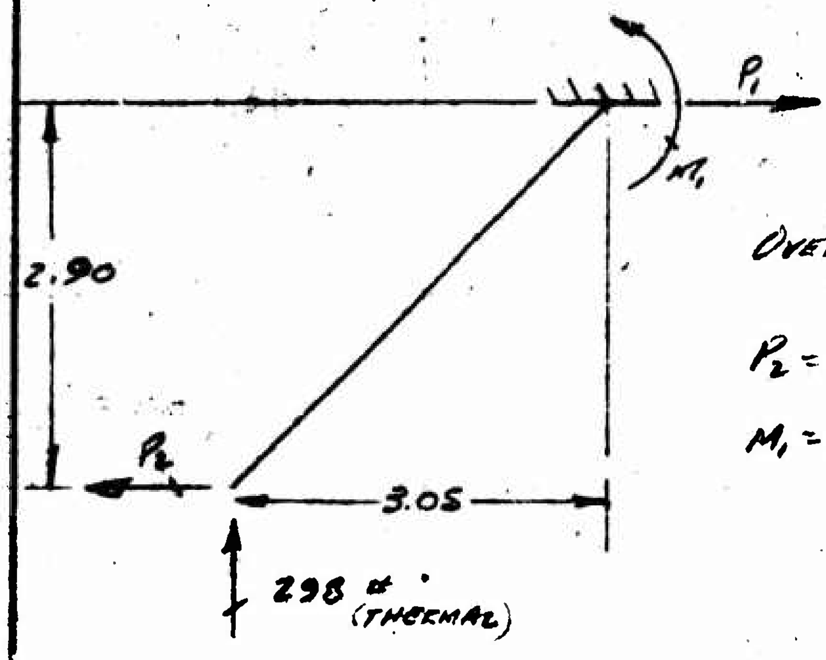
285-0131 BRACKET

MAT'L 4340 STL BAR (FORGED) MIL-S-5000 150,000 H.T.
(FULL SIZE TO SCALE)



THE THICKNESS OF SECTION A-A IS CALCULATED TO BE .707 (.2) = .1414 THK.

285-0181 BRACKET



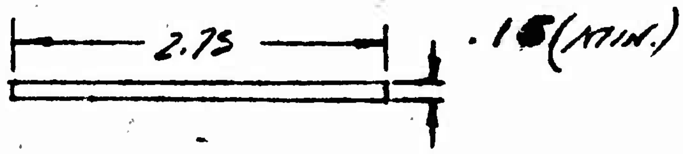
OVER-REV COND. IS CRITICAL

$P_2 = P_1 = 2020/2 = 1010^{\#}$ LIM.

$M_1 = 2.9 \times 1010 = 2930^{\#\prime\prime}$

BRACKET IS TO BE INSTALLED IN SUCH A MANNER AS TO RELIEVE THE THERMAL STRESSES. (REFER TO DWG. 285-0179 & -0160 AND PGS. 5.2.10.7 & .8

SECTION A-A REF. PG. 5.2.10.9



$M = 1010\ (.9) = 909^{\#\prime\prime}$ OVER REV COND

$F_{cy} = 145000 \times .87 = 126000\ psi = F_b$ .87 = TEMP FACTOR

$f_{b\,C.F.\,ONLY} = \frac{6M}{bt^2} = \frac{6(909)}{2.75^*(.15)^2} = 88200\ psi$

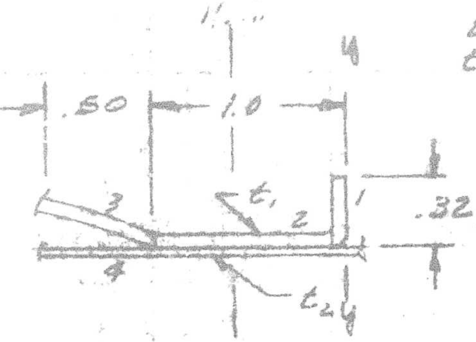
$MS = \frac{126000}{88200} - 1 = \underline{\underline{.43}}$

*.01 ACCOUNTS FOR SLIGHT CURVATURE

ANALYSIS HOT CYCLE
PREPARED BY W.L. ZIEBES 3-21-60
CHECKED BY

BLADE DUCT

285-0175 BALL ASSY



$t_1 = .080$
$t_2 = .020$

MATL 821 or 347

ITEM	AREA	X	AX	AX^2	I_o
1	.0256	.040	.001025	.000041	.000014
2	.0735	.810	.0597	.02140	.0068
3	.040	1.25	.0500	.0625	
4	.030	.75	.0225	.0169	.005630
Σ	.1691		.113225	.100841	.012174

$\bar{X} = \frac{AX}{A} = \frac{.1132}{.1691} = .670 \text{ IN}$

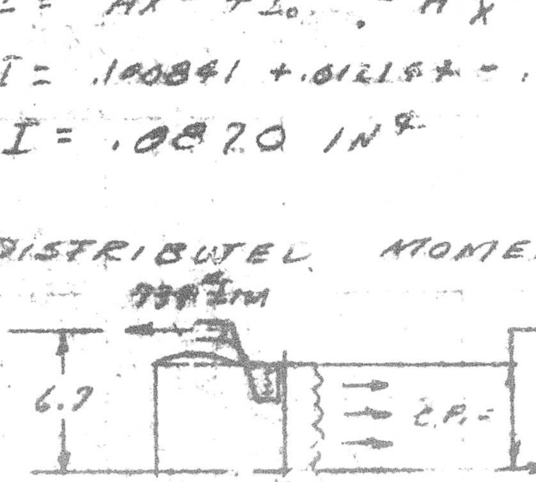
$I = AX^2 + I_o - A\bar{X}^2$

$I = .100841 + .012174 - .076$

$I = .0370 \text{ IN}^4$

$F_b = 15000 \text{ psi}$ AT TEMP. = 1039°F

DISTRIBUTED MOMENT



C.F. = 1468/2 = 734# LIM. CRUISE

$M_o = \frac{734(1.5)(6.7-4.3)}{(\pi)4.27} = 197$ "# (ULT)

$S = \frac{M.R}{I/c} = \frac{197(4.27)(.670)}{.037} = 6450$ psi (ULT)

$M.S. = \frac{15000}{6450} - 1 = 1.32$

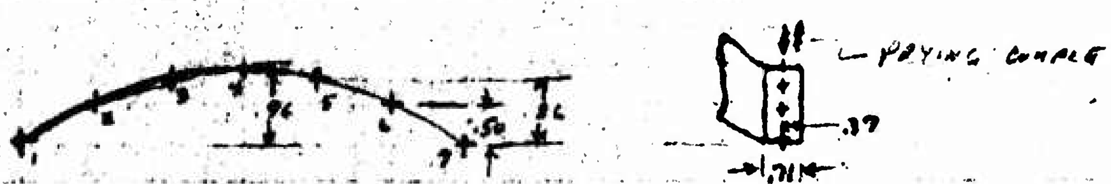
ZB5-0131 BRACKET

ATTACHMENT OF BRACKET TO DUCT

LOADING ON ATTACHMENT

O.R. COND. $M_{im} = 2.9 \times 1010 = 2930$ "# LIM. $P_s = 1010$ #

W.F. COND. $M_{im} = 2.9(727 \pm 8) = 2110 \pm 23$ "# $P_s = 727 \pm 8$ #



$\bar{z} = (2 \times .5 + 2 \times .86 + 4 \times .96)/7 = .55$

$I = 2(.55)^2 + 2(.05)^2 + 2(.31)^2 + 1(.41)^2 =$
$.608 + .005 + .199 + .169 = .976 \text{ in}^2$

MAX. LOAD ON ATTACHMENT (O.R. COND)

$^{\Delta}R_{s_{att}} = \frac{2930(.41)}{.976} + \frac{1010}{7} = 1232 + 144 = 1376$ # LIM.

ALLOWABLE 1/4 HUCK LOCKBOLT DIMPLED & CSK IN THE FOLLOWING LAYERS OF MATERIAL THAT ARE SPOTWELDED TOGETHER
$t_{tot} = .080 + .032 + .020 = .132$ IN. (REF. DWG. 285-0175)

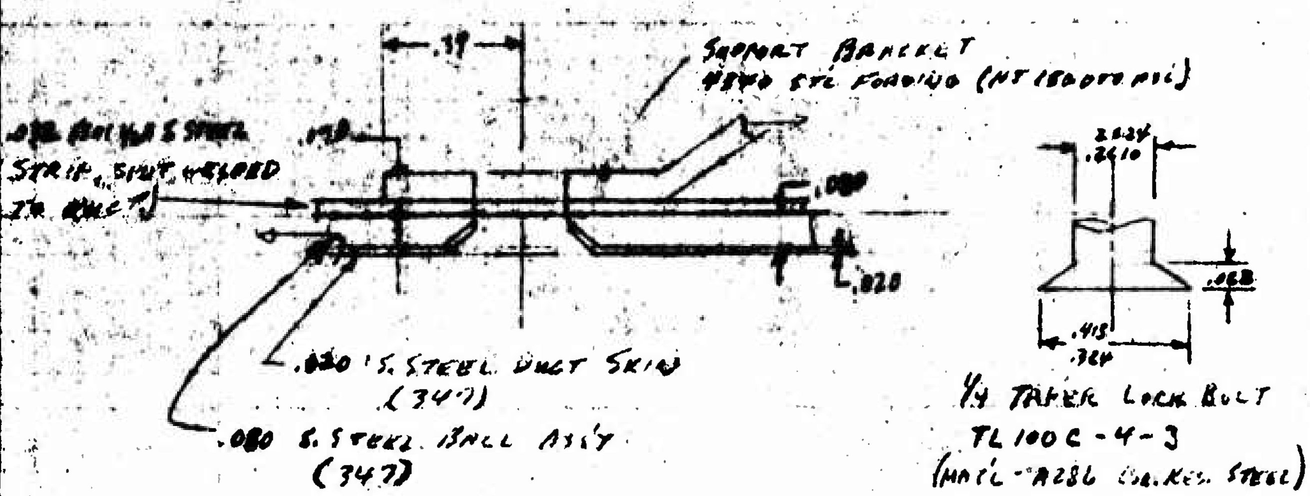
ALLOW. $P_{br} \cong .261 \times .132 \times 70000 = 2410$ LBS @ 1050°F.

CONT'D ON NEXT PAGE.

$^{\Delta}$THE ABOVE ANALYSIS NEGLECTS THE EFFECT OF THE PRYING COUPLE WHICH WOULD REDUCE THE SHEAR LOAD ON THE ATTACHMENTS.

-0131 SUPPORT BRACKET

ATTACHMENT TO -0175 BALL ASS'Y (DUCT)



ALLOWABLE SHEAR OF BOLT @ 1000°F

$A_s = \pi (.1305)^2 = .0535 \text{ in}^2$

$F_{s_u} = 85000 \times .83 = 70500$ psi @ 1000°F

$P_s = 70500 \times .0535 = 3770$ #

ALLOWABLE BEARING IN .078 BRACKET @ 900°F

$A_{br} = .078 \times .261 = .0203 \text{ in}^2$

$F_{br_u} = 194000 \times .69 = 134000$

$P_{br_u} = 134000 \times .0203 = 2720$ #

FROM PREVIOUS PAGE $P_{br} = 2410$

MAX $R_s = 1376$ LBS

$$M.S. = \frac{2410}{1376 \times 1.5} - 1 = \underline{.17}$$

285-0180 HOUSING ASS'Y

OVER-REV. COND.

$P = 1010^{\#}$ LIMIT

$w = \frac{1010 \times 2}{9.8\pi} = 65.6^{\#}/\text{IN LIM.}$

REF. ROARK - CURVED BEAM LOADED NORMAL TO PLANE OF CURVATURE

$R = 4.9''$ $\theta = \pi$

$V_0 = V_1 = \frac{1}{2} w R \theta$
$= \frac{1}{2} \times 65.6 \times 4.9 \times \pi = 505$

$M_0 = wR^2\left(\frac{\sin\frac{1}{2}\theta - \frac{1}{2}\theta\sin\frac{1}{2}\theta}{\sin\frac{1}{2}\theta}\right) = 65.6 \times 4.9^2(1.0) = 1572''^{\#}$ (MAX - M)

$M = -M_0 \cos\alpha + \frac{1}{2} w R^2 \theta \sin\alpha - wR^2(1-\cos\alpha)$

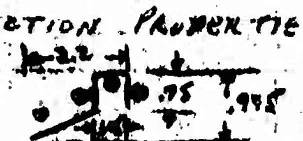
$T = -M_0 \sin\alpha + \frac{1}{2} w R^2 \theta (1-\cos\alpha) + wR^2(\alpha - \sin\alpha)$

$\alpha = \frac{\pi}{2}$

$M = -M_0(0) + \frac{1}{2} w R^2 \left(\frac{\pi}{2}\right)(1.0) - wR^2(1.0)$
$= \frac{1}{2}(65.6)(4.9)^2\left(\frac{\pi}{2}\right) - 65.6(4.9)^2 = 65.6(4.9)^2\left(\frac{\pi}{4} - 1.0\right) = -338''^{\#}$

$T = -M_0(1.0) + \frac{1}{2} w R^2 \left(\frac{\pi}{2}\right)(1-0) + wR^2\left(\frac{\pi}{2} - 1.0\right)$
$= -1572 + \frac{1}{2}(65.6)(4.9)^2\left(\frac{\pi}{2}\right) + 65.6(4.9)^2(.571) = +664''^{\#}$

SECTION PROPERTIES



ITEM	A	X	AX	AX^2	I_0
1	.194	1.68	.233	.377	.0158
2	.0465	1.05	.049	.0513	-
3	.0140	.56	.008	.0229	.0077
4	.1600	0	0	0	-
Σ	.3345		.326	.4510	.0235

$\bar{X} = \frac{.326}{.3345} = .974$ $I_x = .4745 - .3345(.974)^2 = .1575$ IN.^{4}

$f_b = \frac{1572(1.226)}{.1575} = 12220$ PSI LIM

$f_{b_u} = 18400$ PSI ULT

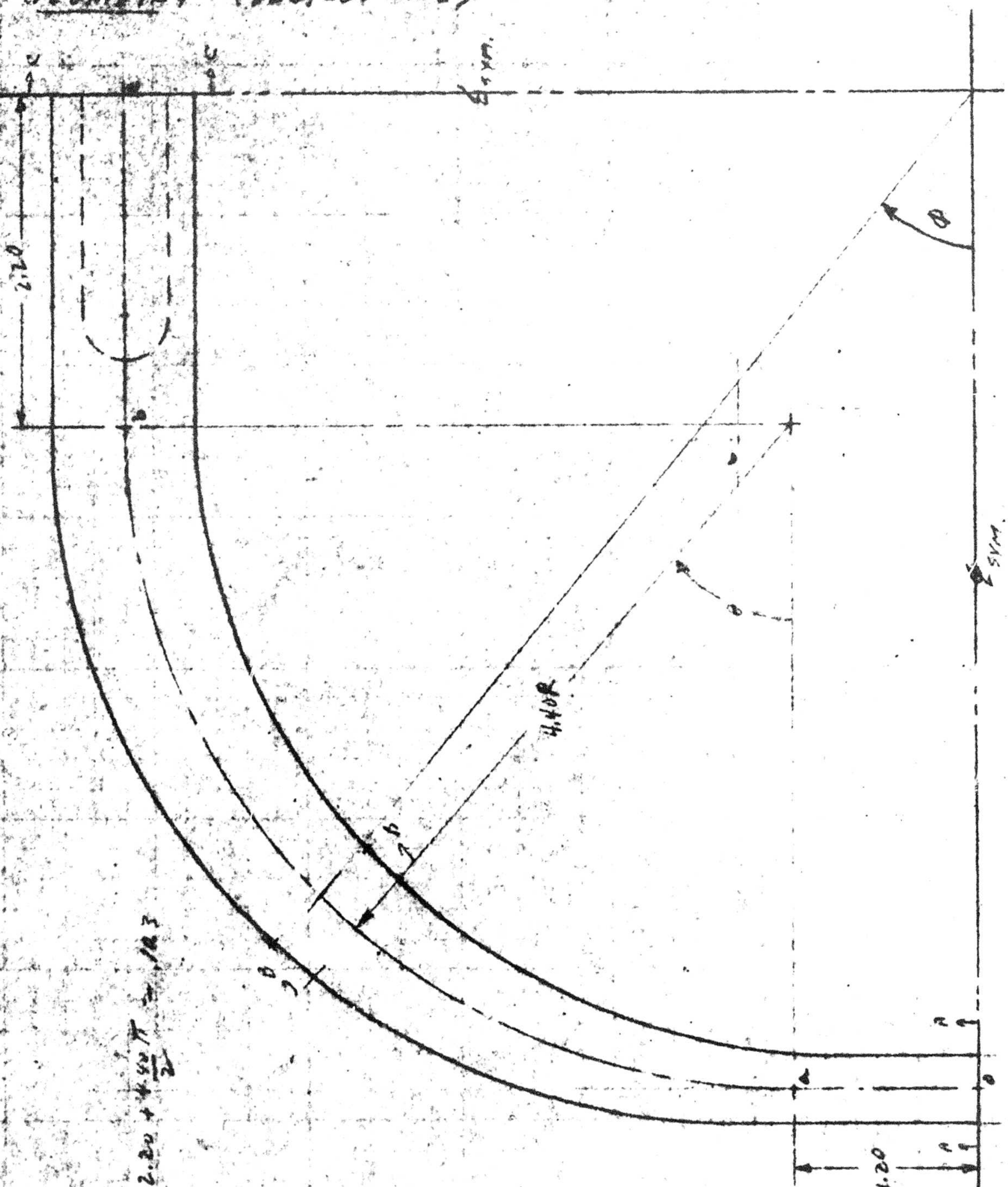
HOUSING IS SATISFACTORY

ANALYSIS
PREPARED BY J. Neumann 4/23/61
CHECKED BY

BLADE DUCT

RING - DUCT GIMBAL

GEOMETRY (DWG. 285-0178)



$\ell = 1.20 + 2.20 + \frac{4.40}{2}\pi = 10.3$

BLADE DUCT

Section Properties

a → b

$A = .437 \times .85 = .372 \text{ in}^2$

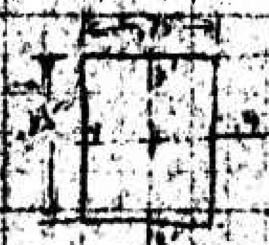
$I_x = \frac{.437(.85)^3}{12} = .0224 \text{ in}^4$

$I_y = \frac{.85(.437)^3}{12} = .00592 \text{ in}^4$

$K_1 \cong \frac{2.65}{16}(.85)(.437)^3 = .0164 \text{ in}^4$

Section A-A

a → b (Pyw.)



$A = .75 \times .85 = .637 \text{ in}^2$

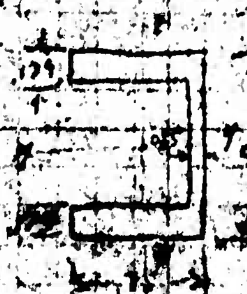
$I_x = \frac{.85(.75)^3}{12} = .0299 \text{ in}^4$

$I_y = \frac{.75(.85)^2}{12} = .0384 \text{ in}^4$

$K_2 \cong \frac{2.5}{16}(.85)(.75)^3 = .0540 \text{ in}^4$

Section B-B (Flattened)

b → c (min. section @ ℄)



$A = .959 \times .75 - .55 \times .665 = .317 \text{ in}^2$

$I_{yy} = \frac{.75(.959)^3}{12} - \frac{.665(.55)^3}{12} = .0514 - .0108 = .0436 \text{ in}^4$

$\bar{y} = [.709 \times .375 - .366 \times .417]/.317 = .322 \text{ in}$

$I_x = \frac{.959(.75)^3}{12} + .709(.375-.322)^2 - \frac{.55(.665)^3}{12} - .366(.417-.322)^2$

$= .0390 + .00187 - .0142 - .00348 = .0173 \text{ in}^4$

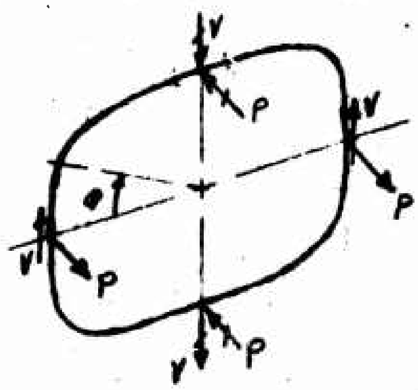
$K_{min} \cong \frac{[2 \times .75(.179)^3 + .55(.085)^3] + \frac{.317}{16}(.032)(.75)^3}{3} = .024$

For Torque Shear Stress $f_s = T t / K$

$\text{eff. } At^2 = 2(.75)(.179)^2 + .579(.085)^2 = .0522 \text{ in.}^3$

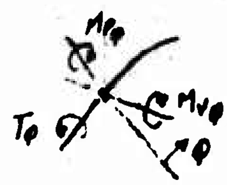
RING – DUCT GIMBAL

CENTRIFUGAL FORCE & PRESSURE LOADING (P) AND FOR VERTICAL LOADING (V)



OVER-REV. COND, $P = 1010$ LBS. LIM.
$V \cong 0$

WT. FAT. COND. $P = 727 \pm 8$ LBS. LIM.
$V = 130 \pm 63$ LBS. LIM.



FROM A STRAIN-ENERGY SOLUTION OF THE RING, THE MOMENT AND TORQUE AT THE CRITICAL SECTION ($\phi = 90°$) IS GIVEN BELOW:

$M_{P_{90}} = 3.09(1010) = 3120$ "# LIM.
$T_{90} = .47(1010) = 475$ "# LIM
} OVER-REV. COND.

$M_{P_{90}} = 3.09(727 \pm 8) = 2250 \pm 25$ IN.LBS
$T_{90} = .47(727 \pm 8) = 342 \pm 3.7$ IN.LBS.
$M_{V_{90}} = 5.20(130 \pm 63) = 676 \pm 328$ IN.LBS.
} WT. FATIGUE COND.

STRESSES AT CRITICAL SECTION
(FOR SECTION PROPERTIES SEE PG. 5.2.10.17

OVER-REV. COND.

$f_{b_c} = \frac{3120(.428)}{.0173} = 77200$ psi LIM. $f_{b_{c\,ULT}} = 116000$ psi

$f_{b_t} = \frac{3120(.322)}{.0173} = 58000$ psi LIM. $f_{b_{t\,ULT}} = 87000$ psi

$f_{s_T} = 3(475)/.0522 = 27300$ psi LIM $f_{s_T} = 41000$ psi

$F_b = 160000 \times 1.5 \times .9^{\Delta} = 216000$ psi $F_{s_u} = 100000 \times .95^{\Delta} = 95000$ psi

$M.S. = \frac{216000}{116000} - 1 = \underline{.86}$

$R_b = \frac{87000}{216000} = .402$ $R_s = \frac{41000}{95000} = .432$

Δ TEMP. REDUCTION FACTOR @ 500°F $M.S. = \frac{1}{[(.402)^2 + (.432)^2]^{1/2}} - 1 = \underline{\underline{.69}}$

.591

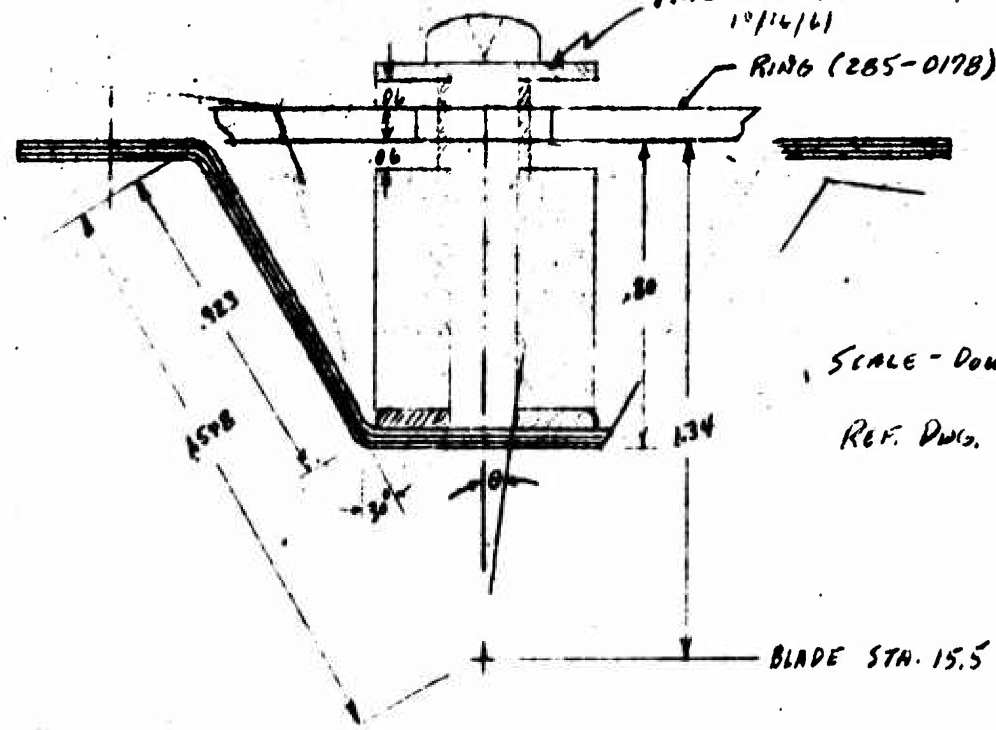
HUGHES TOOL COMPANY-AIRCRAFT DIVISION

MODEL 285 REPORT NO. 285-13 PAGE 5.2.10.18

ANALYSIS
PREPARED BY J. NEEDHAM 6/7/60
CHECKED BY

BLADE DUCT

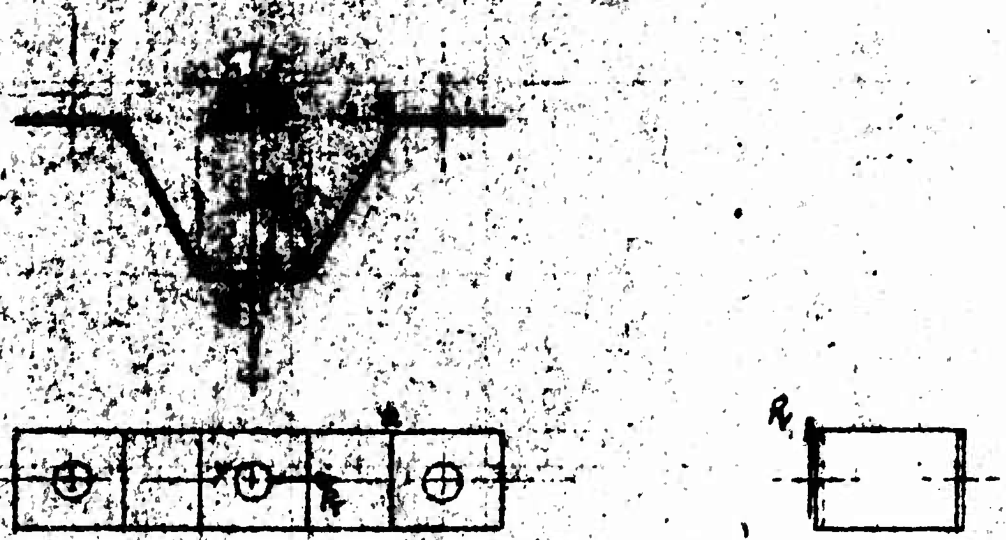
FLEXURE - STA. 15.5



THE JOINT BETWEEN THE INBOARD DUCT AND OUTBOARD DUCT AT STA. 42.5 WAS DESIGNED TO ALLOW THE DUCTS TO MOVE AND ROTATE RELATIVE TO ONE ANOTHER. DURING THE TEST OF THE HOT CYCLE ROTOR BLADES IT WAS FOUND THAT A FRICTION LOAD EXISTS AT THE JOINT. THE FRICTION LOADING ADDS TO THE BASIC CENTRIFUGAL FORCE AND PRESSURE LOADS. ON THE FOLLOWING PAGES IS A SUMMARY OF THE LOADS ACTING ON THE FLEXURE AND THE RESULTING COMPUTED STRESSES IN THE FLEXURE. THE STRENGTH OF THE FLEXURE IS MARGINAL THEREFORE THE FAIL SAFE FEATURE SHOWN ABOVE WAS ADDED.

8704

DUCT FLEXURE @ STA. 15.5



THE FLEXURE IS LOADED IN THREE DIRECTIONS, P_c, P_v & P_T AND IS DEFLECTED AN ANGLE θ. ALL THE LOADS AND THE DEFLECTION MAY OCCUR SIMULTANEOUSLY. BELOW ARE LISTED THE LOADS, THE CONDITIONS PRODUCING THE LOADS AND THE COMPUTED STRESSES AT THE CRITICAL SECTION 'B'.

ROTATION - θ

FOR WEIGHTED FATIGUE COND. - $\theta = \pm 0°31'$

$f_{b_{wgt}} = \pm 21100$ psi (BENDING)

LOAD P_c

P_c IS AN AXIAL LOAD AND IS A COMBINATION OF THREE TYPES OF LOADS. THE LOADS ARE A CENTRIFUGAL FORCE LOAD, A PRESSURE LOAD, AND A FRICTION LOAD FROM THE LIP SEAL AT STA. 42.

CENTRIFUGAL FORCE LOAD IS BASED ON A BLADE TIP SPEED OF [illegible] FT/MIN. AND A WEIGHT OF INBOARD DUCT OF 280 LBS.

LOAD PER FLEXURE = 420 ± 3

DUCT FLEXURE @ STA. 15.5

LOAD P_c (CONT'D)

PRESSURE LOAD IS BASED ON A DUCT PRESSURE OF 30 PSI

LOAD PER FLEXURE = 292 ± 5 LBS.

FRICTION LOAD USED IS ± 200 LBS.

TOTAL AXIAL LOAD ON THE FLEXURE IS

P_c = 712 ± 208 LBS WHICH PRODUCES A STRESS OF

f_c = 11000 ± 3200 psi (AXIAL)

LOAD P_V

P_V IS A VERTICAL SHEAR LOAD AND IS THE COMBINATION OF THREE TYPES OF LOADS. THE LOADS ARE A CENTRIFUGAL FORCE LOAD, AN INTERNAL DUCT PRESSURE LOAD AND AN EXPANSION LOAD DUE TO TEMPERATURE DIFFERENTIALS.

THE CENTRIFUGAL FORCE LOAD AND DUCT PRESSURE LOAD ARE THE SAME AS FOR THE AXIAL LOAD, P_c, WITH A HUB TILT OF 6° AND A CONING ANGLE OF 6°.

C.F. LOAD P_V = 30 ± 15 LBS.

f_b = 4200 ± 2100 PSI

DUCT PRES. LOAD P_V = 99 ± 47 LBS.

f_b = 13600 ± 6600 PSI

TOTAL f_b = 17800 ± 8700 PSI (BENDING)

A DIFFERENTIAL TEMPERATURE OF 100°F BETWEEN THE GIMBAL RING AND HOUSING RESULTS IN A STEADY BENDING STRESS IN THE FLEXURE OF

f_b = 7000 PSI

DUCT FLEXURE @ STA. 15.5

LOAD P_T

P_T IS A SIDE LOAD IN THE FLEXURES RESULTING FROM THE TORSIONAL FORCE REQUIRED TO ROTATE THE INBOARD DUCT IN THE LIP SEAL AT STA. 42. THE MEASURED VALUE OF THIS TORQUE HAS VARIED FROM 400 TO 1000 IN. LBS. FOR A CYCLIC TORQUE OF 450 IN. LBS.

$$P_T = \pm 40 \text{ LBS.}$$

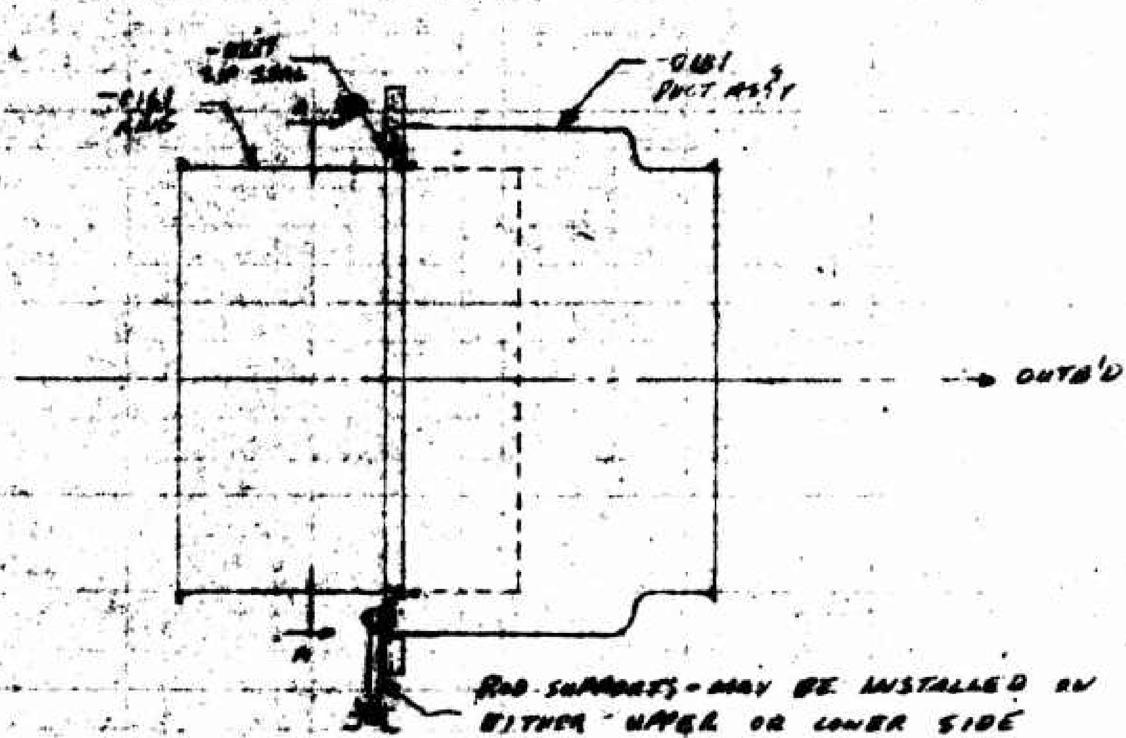
$$f_{cyc} = f_b + f_a = \pm 8500 \pm 500 = \pm 9000 \text{ psi}$$

THE STRESS LEVEL FOR THE DESIGN WEIGHTED FATIGUE CONDITION, ASSUMING THE FOLLOWING, AN AXIAL FRICTION LOAD OF ± 400 LBS, A CYCLIC TORQUE OF ± 450 IN. LBS. AND A 410°F TEMPERATURE DIFFERENTIAL BETWEEN RING AND HOUSING IS AT POINT 'B'. ASSUMING ALL CYCLIC STRESSES ADD. (CONSERVATIVE)

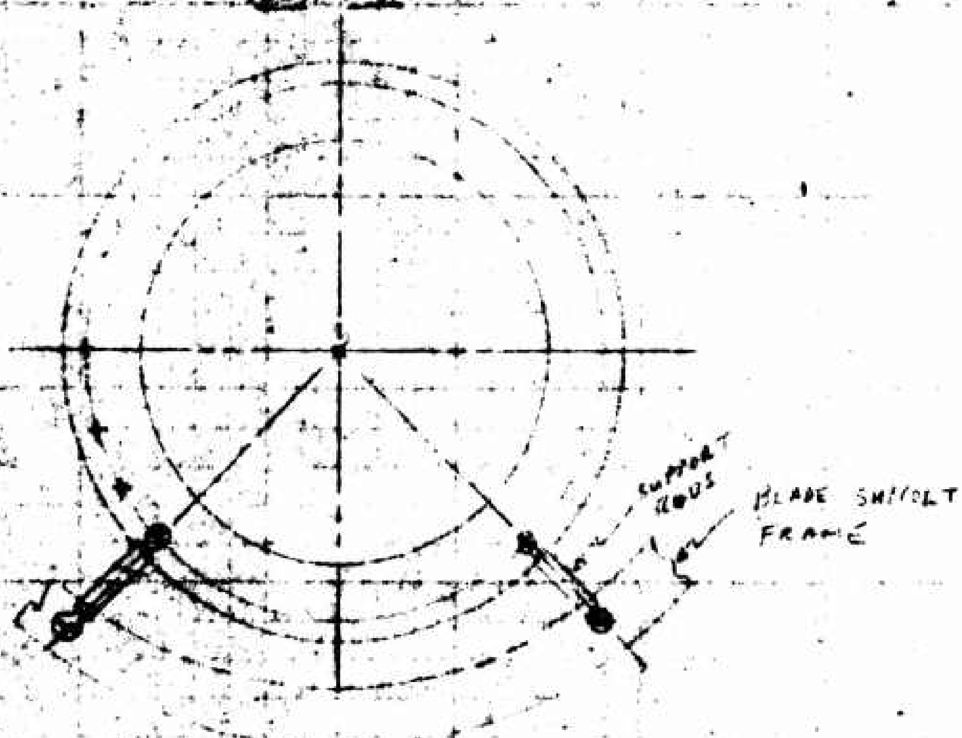
$$f_{max} = 57000 \pm 42{,}000 \text{ psi}$$

BLADE DUCT

CENTER SUPPORT (DWG. 285-0162)



SECT. A-A



HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS MODEL 285 REPORT NO. 285-13 PAGE 5.2.10.28

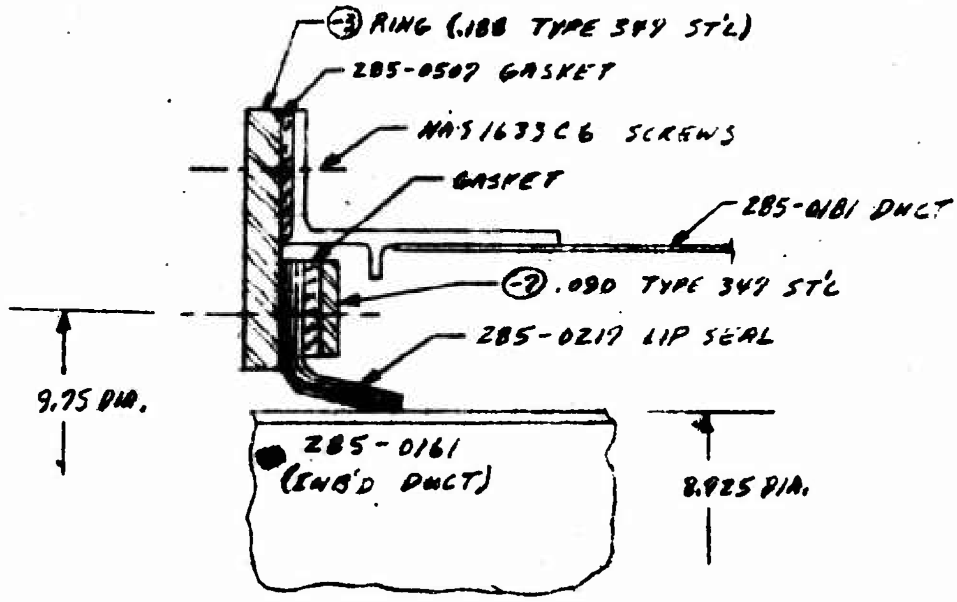
PREPARED BY J. NEEDHAM 9/61 BLADE DUCT

CHECKED BY

LIP SEAL - STA. 42.5

REF DWG. 285-0217
DWG. 285-0204

CROSS-SECTION AT THE SUPPORT OF THE INBOARD DUCT BY THE OUTBOARD DUCT THRU THE LIP SEAL.



THE LIP SEAL IS MADE OF (3) SHEETS OF .010 RENE 41 MATERIAL. THE SEAL IS STIFFENED AT THE TOP AND BOTTOM BY (2) DOUBLERS MADE OF .020 RENE 41. EACH LAYER OF THE LIP SEAL IS SLOTTED AT 24 EVENLY SPACED POINTS AROUND THE CIRCUMFERENCE. THE LAYERS WERE ROTATED RELATIVE TO EACH OTHER SO THAT THE SLOTS WOULD NOT COINCIDE.

THE MAXIMUM COMPUTED CYCLIC BENDING STRESS IN THE LIP SEAL WAS $f_b = 36900 \pm 36900$ psi

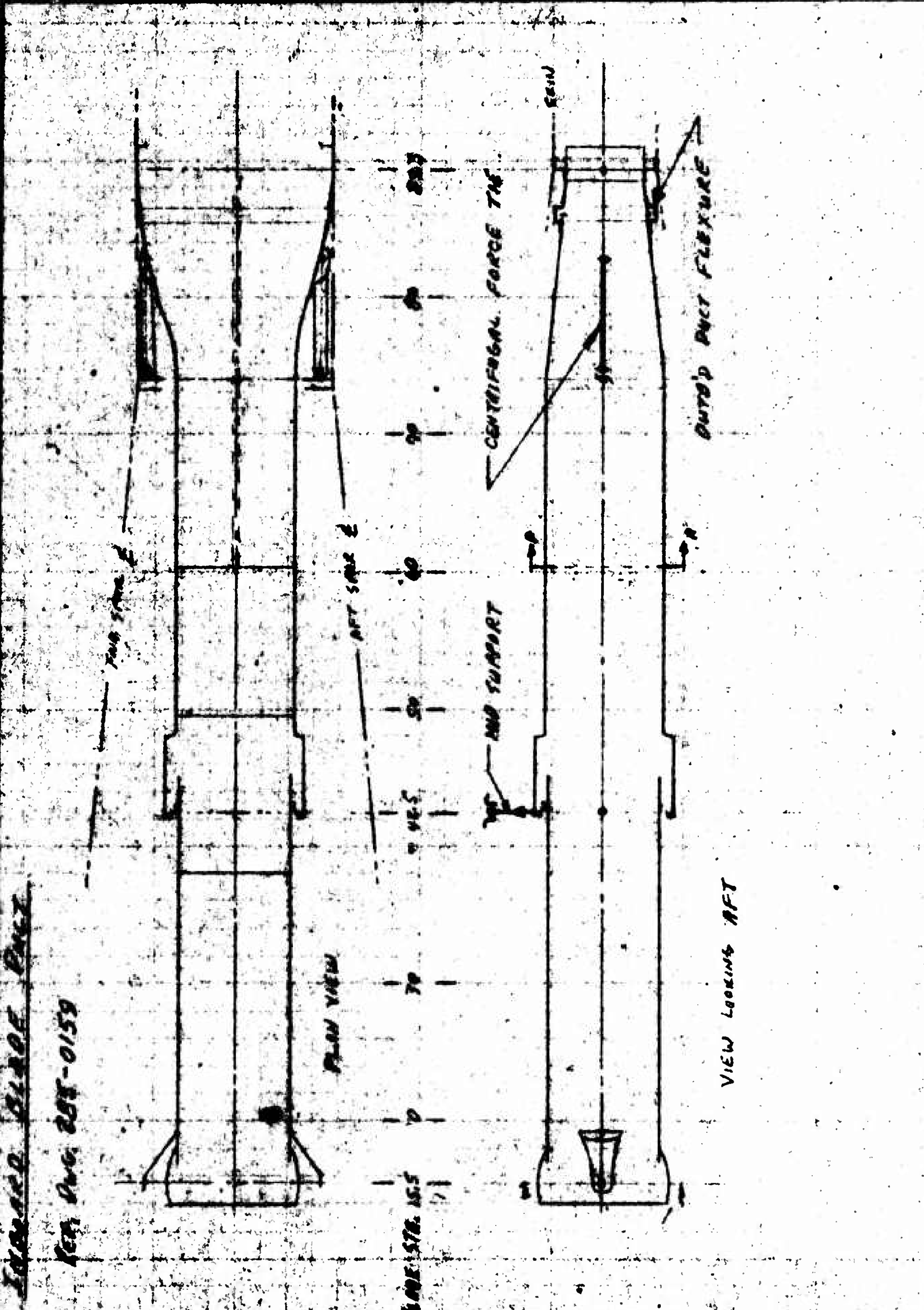
THE LIP SEAL WAS TESTED AND IS STRUCTURALLY SATISFACTORY. THE TEST RESULTS ARE GIVEN RPT. 285.9.8 SECT. 6.4

8704

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

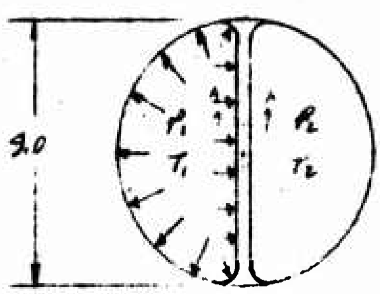
MODEL 285 REPORT NO. 285-13

TITLE: BLADE DUCT



OUTB'D DUCT @ STA. 60.5

DUCT IS A CIRCULAR SECTION DIVIDED AT CENTERLINE INTO TWO SECTIONS. FOR NORMAL OPERATION BOTH SECTIONS ARE EQUALLY PRESSURIZED AND LOADS ARE CARRIED BY HOOP TENSION. FOR ONE ENGINE OPERATION THERE IS A PRESSURE AND TEMPERATURE ACROSS THE DIVIDING WEB AND POSTS.



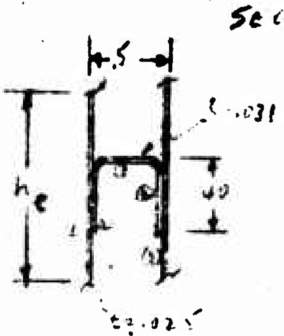
SPACING OF POSTS = 2.0"

$T_1 - T_2 = 600°F$

$P_1 - P_2 = 23.6$ psi LIM

MAX B. MOM $= \frac{23.6 \times 2 (9)^2}{8} = 477$ in-lb LIM

SECT. A-A (PG 5.2.10.24)



$h_t = 2.0"$ TENSION SIDE

$h_c = 30t = 30(.025) = .75"$ COMP. SIDE

MATERIAL - INCONEL 'X'

ITEM	A	y	Ay	Ay²	I_o
1	.0188	.012	.00023	—	—
2	.0124	.040	.00050	.00002	
3	.0120	.250	.00300	.000750	.00015
4	.0124	.460	.00570	.00262	
5	.0500	.487	.02396	.01140	—
Σ	.1056		.03333	.01499	.00015

$\bar{y} = \frac{.03333}{.1056} = .316$ $\qquad I_{NA} = .01499 - .1056(.316)^2 = .00444 \text{ in}^4$

$f_{b_t} = \frac{477(.184)}{.00444} = 19800$ psi

$f_{b_c} = \frac{477(.316)}{.00444} = 34000$ psi

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

MODEL 285 REPORT NO. 285-13 PAGE 52.10.26

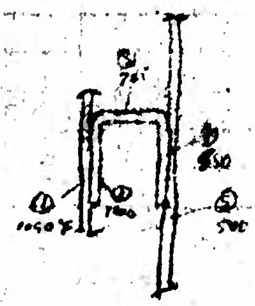
ANALYSIS
PREPARED BY W. NEEDHAM 5/12/52
CHECKED BY

BLADE DUCT

<u>ROTA'D RACT. STA. 60.5</u>

REF DWG 285-0132

<u>CENTER POST - THERMAL STRESS</u>



$b/t = \frac{.40}{.031} = 12.9$

$F_{cr_{y,n}} = .525 \times 26 \times 10^6 \left(\frac{1}{12.9}\right)^2 = 82\,000$ psi

$F_{cy} = 50{,}000$ psi

ITEM	A	ΔT	α $\times 10^6$	E $\times 10^{-6}$	f	ΔP	ΣΔP/ΣA	f_{RES}
1	.0188	950	8.2	24.2	188200	3540	123500	-64700
2	.0124	900	8.15	24.7	181000	2240	″	-57500
3	.0120	625	8.0	26.9	134500	1610		-11000
4	.0124	450	7.85	28.0	99000	1230		24500
5	.0500	400	7.8	28.3	88400	4410	123500	35100
Σ	.1056					13030		

COMBINED STRESS ON ITEM (1) PRES. + THERMAL

$f_c = 34000 + 64700 = 98{,}700$ psi COMP.

$F_c = 105{,}000 \times .90 = 94{,}500$ psi

THE ANALYSIS SHOWS POSSIBLE YIELDING OF THE CENTER DIVIDER. THE STRUCTURE IS SATISFACTORY FOR A ONE ENGINE OPERATION AS AN EMERGENCY CONDITION. DESIGN IS INVESTIGATING THE INCORPORATION OF THE SHUT-OFF VALVE WITH THE TIP CASCADE THEREBY ELIMINATING THIS CONDITION.

<u>PRIMARY HOOP STRESS IN THE DUCT</u>

BURST PRESSURE = 60 psi ULT.

$f_t = \frac{60(4.5)}{.025} = 10{,}800$ psi M.S. → <u>HIGH</u>

FLEXURE AT ATTACH OF DUCT TO BLADE

THERMAL EXPANS. OF DUCT & SPARS BETWEEN STA. 73 & 90

DUCT:

MATERIAL - INCONEL X . TEMP. 1000°

$\alpha\ (100 \rightarrow 1000°F) = 10 \times 10^{-6}$ in/in/°F

$\delta_{D} = (1000-70)(17)(10\times10^{-6}) = .158''$

SPARS:

MATERIAL - TITANIUM ALLOY TEMP = 400° AVG.

$\alpha\ (100 \rightarrow 500°) = 5.0 \times 10^{-6}$ in/in/°F.

$\delta_{SP} = (400-70)(17)(5.0\times10^{-6}) = .028''$

DIFFERENCE IN THERMAL DEFL. OF DUCT & SPAR.

$\Delta = .158 - .028 = .13''$

SPAR ELONGATION DUE TO C.F. - STA. 73 TO 90

$f_{C.F.} = 39000$ psi (WT. FATIGUE COND.)

$\delta_{C.F.} = \dfrac{39000\,(17)}{29\times10^{6}} = .0223$ NET $\Delta = .13 - .022 = .108$

THIS REDUCES THE THERMAL DEFLECTION BETWEEN SPAR & DUCT

FOR OVER-REV COND.

$\Delta_{C.F.} = .0223 \times 1.57 = .035''$ NET $\Delta = .13 - .035 = .095$

THE FLEXURE IS STRETCHED AT ROOM TEMPERATURE .07 INCHES TO REDUCE THE STEADY STRESS WHEN THE FLEXURE IS UNDER LOAD AND AT TEMPERATURE. REF DWG. 285-0159

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS
PREPARED BY J. NEEDHAM 4/8/60
CHECKED BY

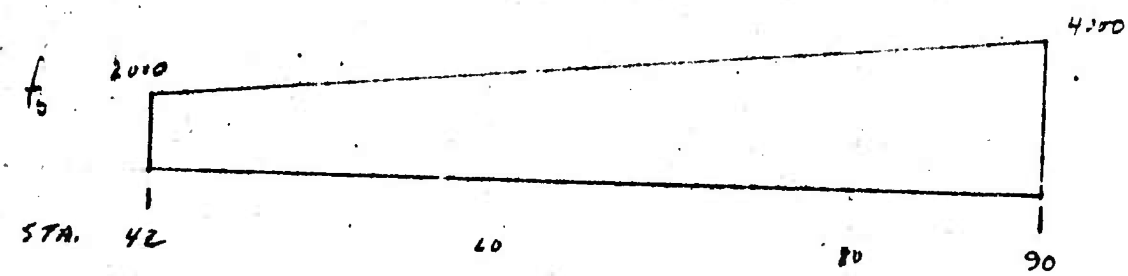
MODEL 285 REPORT NO. 285-13 PAGE 5.2.10.28

BLADE DUCT

FLEXURE @ ATTACH OF DUCT TO BLADE

RELATIVE ROTATION OF OUTB'D END OF DUCT AND SPAR FROM STA. 42 TO 90

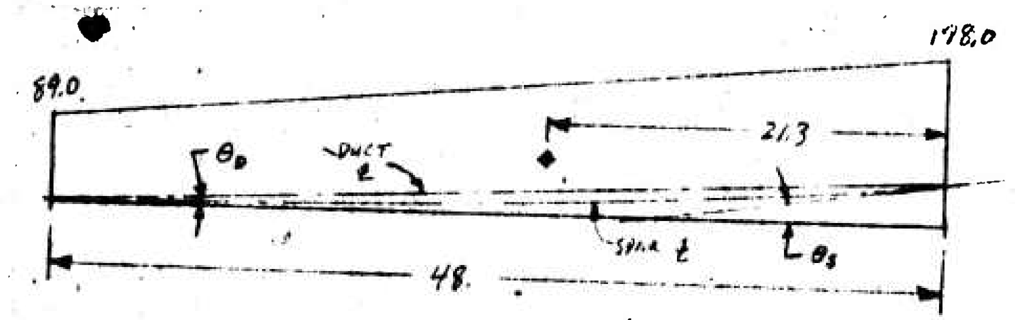
$\frac{f_b}{1.5E}$



$$\frac{M}{EI} = \frac{f_b}{cE} \qquad c = 1.5 \qquad E = 15 \times 10^6$$

$$\frac{M}{EI} = \frac{f_b}{1.5 \times 15 \times 10^6} = .0445\, f_b \times 10^{-6}$$

$(10^6)\frac{M}{EI}$



$$\theta_S = \frac{(89.0 + 178.0)}{2}(48)(10^{-6}) = 6410 \times 10^{-6} \text{ RAD (SPAR ROTATION)}$$

$$\delta_{90} = .00641\,(21.3) = .1368''$$

ROTATION OF DUCT $\theta_D = \frac{.1368}{48.} = .00284$ RAD.

DIFFERENCE IN ROTATION OF SPAR BASIC STRUCTURE AND DUCT ℄.

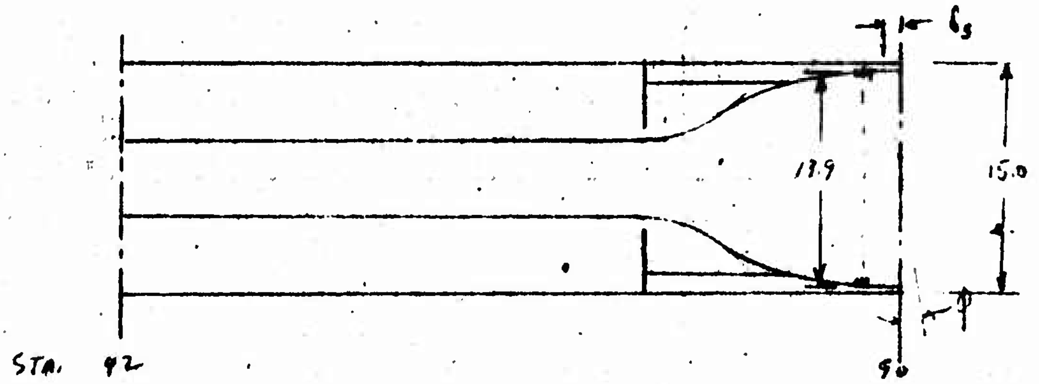
$$\Delta\theta = .00641 - .00284 = .00357 \text{ RAD.}$$

DEFLECTION OF SKIN FLEXURE INB'D OF SKIN TO DUCT ATTACH.

$$\text{MAX. } \delta = 2.5\,(\pm .00357) = \pm .0089'' \text{ (@ MAX FLEX. DEPTH)}$$

FLEXURE AT ATTACH OF DUCT TO BLADE

RELATIVE ROTATION OF OUTB'D END OF DUCT AND SPARS FROM STA. 42 TO 90 IN CHORDWISE DIRECTION



ASSUME THE AVERAGE CYCLIC STRESS IN THE SPARS IS ±3000 psi.

$$\delta_s = \frac{\pm 3000\,(48)}{15 \times 10^6} = \pm .0096'' \qquad \phi = \frac{2\,(.0096)}{15} = \pm .00128 \text{ RAD}$$

$$\delta_{FLEX} = \pm \frac{.00128 \times 13.9}{2} = \pm .0089''$$

COMPUTED CYCLIC AXIAL STRESS IN SPARS REVISED (6-5-60)

@ STA 60 $f_c = \pm 1700$ psi

@ STA 74 $f_c = \pm 2100$

@ STA 90 $f_c = \pm 1900$

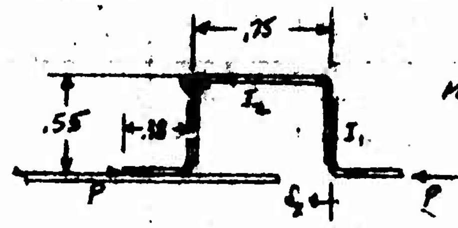
LET AVERAGE AXIAL STRESS FROM STA 63 TO 90 = $f_c = \pm 2000$ psi

$$\delta_s = \frac{\pm 2000\,(27)}{15 \times 10^6} = \pm .0036'' \qquad \phi = \frac{2\,(.0036)}{15} = \pm .00048 \text{ RAD.}$$

$$\delta_{FLEX} = \pm \frac{.00048 \times 13.9}{2} = \pm .00334 \text{ (AT ENDS OF FLEX.)}$$

FLEXURE AT ATTACH. OF DUCT TO BLADE

CROSS-SECTION OF FLEXURE AT CRITICAL SECTION.
(DWG. 285-0195)



MAT'L - .012 INCONEL 'X'

CYCLIC DEFLECTION (δ_x) FOR THE WEIGHTED FATIGUE COND.

$$\delta_x = 25(\pm.00357) + 3.0(\pm.00048) = \pm.0104 \text{ IN.}$$

FROM A STRAIN-ENERGY SOLUTION OF THE FLEXURE WHERE MAX. MOMENT $= (.55/2)P = .275P$ AND IN TERMS OF I_2.

$$P = \frac{E I_2 \delta_x}{(.0208h^3 + .250dh^2)} \qquad E = 30\times10^6$$

$$I_2 = .0833(.012)^3 = .144\times10^{-6}$$

$$P = \frac{30\times10^6 \times .144\times10^{-6}(\pm.0104)}{[.0208(.55)^3 + .250(.75)(.55)^2]} = \pm.75 \text{ LBS}$$

$$\text{MOM.} = \pm.75(.275) = \pm.206 \text{ IN.LBS.}$$

$$f_b = \frac{\pm.206(6)}{(.012)^2} = \pm 8600 \text{ PSI}$$

$F_{b\,cyc} \cong 12000$ psi @ 1000°F

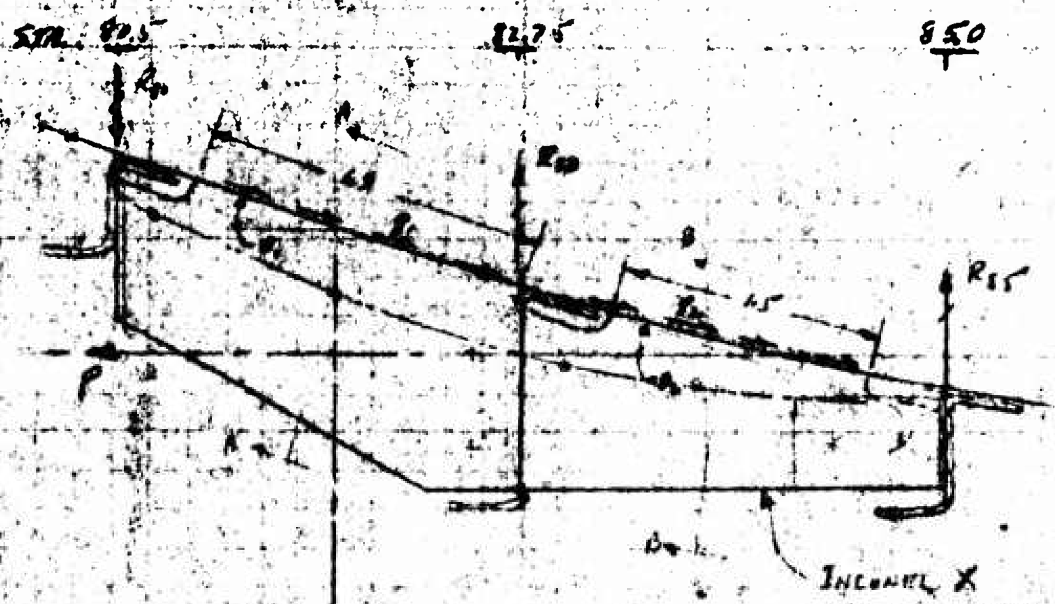
$$M.S. = \frac{12000}{8600} - 1 = .39$$

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

MODEL 285 REPORT NO. 285-13 PAGE 52.1631

J. NEEDHAM — BLADE DUCT

OUTB'D DUCT CENTRIFUGAL FORCE TIE STA. 81.7



$\theta_1 = 17.0°$ $\theta_2 = 13.0°$

$\sin\theta_1 = .292$ $\sin\theta_2 = .225$

$\cos\theta_1 = .956$ $\cos\theta_2 = .974$

$1.9 q_1 \cos\theta_1 + 1.5 q_2 \cos\theta_2 = P$

$R_{80} + R_{83} + R_{85} = 1.9 q_1 \sin\theta_1 + 1.5 q_2 \sin\theta_2$

Let $q_1 = q_2 = q$

$\therefore q = P/(1.9\cos\theta_1 + 1.5\cos\theta_2) = \frac{P}{1.9 \times .956 + 1.5 \times .974} = .305\,P$

$R_{80} + R_{83} + R_{85} = (1.9 \times .292 + 1.5 \times .225).305P = .272\,P$

$P = 4600$ # ULT.

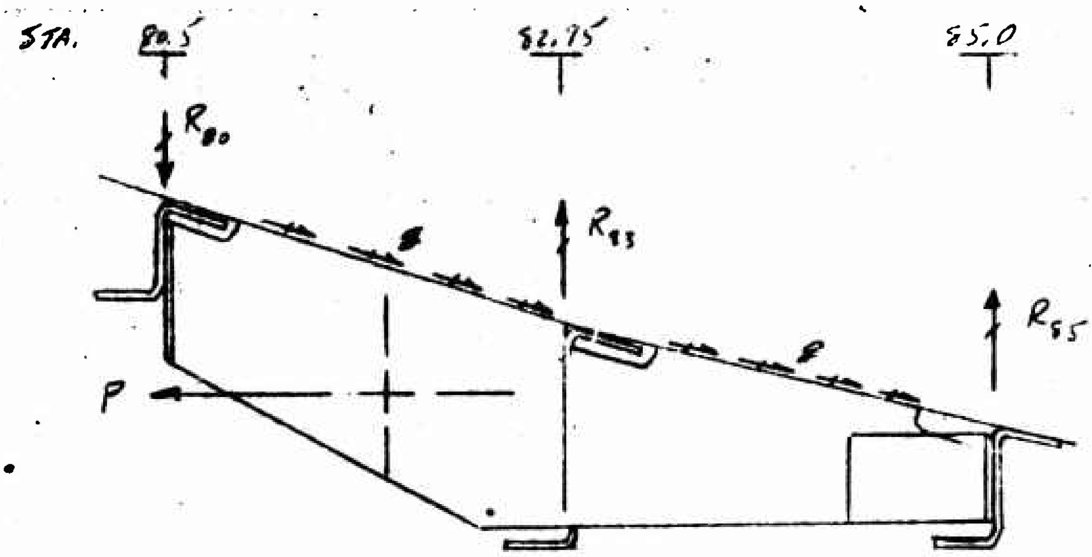
$q = 4600(.305) = 1402$ #/IN   Total load $= 1402 \times 3.4 = 4770$ #

$R_{80} + R_{83} + R_{85} = .272(4600) = 1250$ #

(...) $= \frac{4770}{16} = 298$ #/SPOT

OUTB'D DUCT BRACKET FOR C.F. LOAD

FRAME REACTIONS FOR OVER-REV. COND.



OVER-REV COND.

$^{\blacktriangle}P = 4600\ \#$ ULT.

$q = 1402\ \#/IN$

$R_{80} = 218\ \#$

$R_{83} = 976$

$R_{85} = 493$

▲ ASSUMES 60% OF TOTAL CENTRIFUGAL FORCE LOAD TO ONE BRACKET. FOR TOTAL P_{CF} SEE PAGE 5.2.10.4

OUTB'D DUCT - C.F. TIE STA. 81.9

SECTION @ MAX. MOM.

t = .09

.030 DOUBLER

1.10

.2 .5

$A = 2(.5)(.07) + 2(1.03)(.09) + 1.05(.03) = .245 \text{ in.}^2$

$\bar{y} = \frac{.144 \times .585}{.245} = .344''$

$I = .144(.231)^2 + .070(.309)^2 + .031(.359)^2 + \frac{2(.09)(1.03)^3}{12}$
$= .00769 + .00669 + .00399 + .01275 = .0311 \text{ in.}^4$

LOADS

$S = 218 + 1402 \times .855 \times .292 = 568^{\#}$

$A = 4670 - 1402 \times .855 \times .956 = 3454^{\#}$

MOM $= 1371''^{\#}$

$f_t = \frac{3454}{.245} = 14100$ PSI ULT. FOR $t = .050$ $f_t \approx 19800$ PSI

$f_b = \frac{1371(.755)}{.0311} = 33300$ PSI ULT. $f_b \approx 46600$ PSI

F_{TU} (INCONEL X) @ 1000°F $= 150000 \times .85 = 127500$

M.S. HIGH

ATTACHMENT OF STRAP TO BEAM.

1/4 BOLT BEARING IN (2) SHEETS OF .070 INCONEL X @ TEMP. 1000°F

$P_{br} = 2 \times .25 \times .070 \times 216000 \times .73 = 7300^{\#}$

IF t REDUCED TO .050

$P_{br} = \left(\frac{.050}{.070}\right) 7300 = 5220^{\#}$ M.S. $= \frac{5220}{4600} - 1 = .13$

1.10
.345
.755

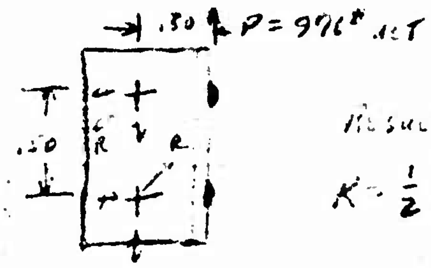
18.0
9.3
27.3

OUTB'D DUCT C.F. TIE STA. 81.9

ATTACHMENT OF BEAM TO DUCT

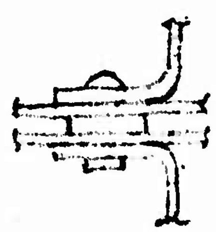
@ STA. 82.85

BEAM TIES TO (2) ANGLE CLIPS BY (2) 1/8 MONEL RIVETS
t OF ANGLES = .037 - ANGLES ATTACH TO FRAMES
BY SPOTWELDS.



RESULTANT LOAD ON RIVET

$$R = \frac{1}{2}\left[\frac{976}{2} + \frac{976(.3)}{.5}\right] = 460^{\#}$$



SHANK SHEAR OF 1/8 MONEL RIVET @ R.TEMP.

$P_s = 600^{\#}$ BASED ON $F_{su} = 49000$ PSI
(MONEL IN SOFT CONDITION)

1/8 RIVET BRG. IN .037 INCONEL X @ 800°F ($F_{br_u} = 286000 \times .81 = 232000$ PSI)

$P_{br} = .128 \times .037 \times 232000 = 1100^{\#}$

$$M.S. \text{ (BASED ON R. TEMP)} = \frac{600}{460} - 1 = \underline{.31}$$

ATTACHMENT OF ANGLE CLIPS TO FRAME BY (8) SPOTWELDS

$$P_s = \frac{976}{8} = 122^{\#}/\text{SPOT}$$

CLASS A SPOT t = .036 R. TEMP VALUE $P_s = 1250^{\#}$

M.S. → HIGH

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

285 · 285-16 · 52 M 35

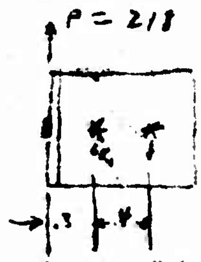
J. NEEDHAM · BLADE DUCT

OUTB'D DUCT C.F. TIE @ STA. 81.7

ATTACHMENT OF BEAM TO DUCT

@ STA. 80.62

BEAM TIES TO (2) ANGLE CLIPS WITH (2) SPOTWELDS PER CLIP



$R_1 = \frac{1}{2}\left[\frac{218}{2} + \frac{218 \times .7}{.4}\right] = 245^{\#}$

ALLOW @ R. TEMP = 1250#

M.S. — HIGH

BOLT REQ'D TO TIE STRAP TO FITTING

LOAD = 4600# ULT IN DOUBLE SHEAR

TEMPERATURE = 900°F

USE NAS 1004 (1/4) A-286 CORR. RES. STEEL F_{tu} = 135000 MIN @ R. TEMP

$F_{su} = 85000 \times .86 = 73500$ psi @ 900°F

$P_s = 73000 \times .049 = 3580^{\#}$ SINGLE SHEAR

$M.S. = \frac{2 \times 3510}{4600} - 1 = \underline{.55}$

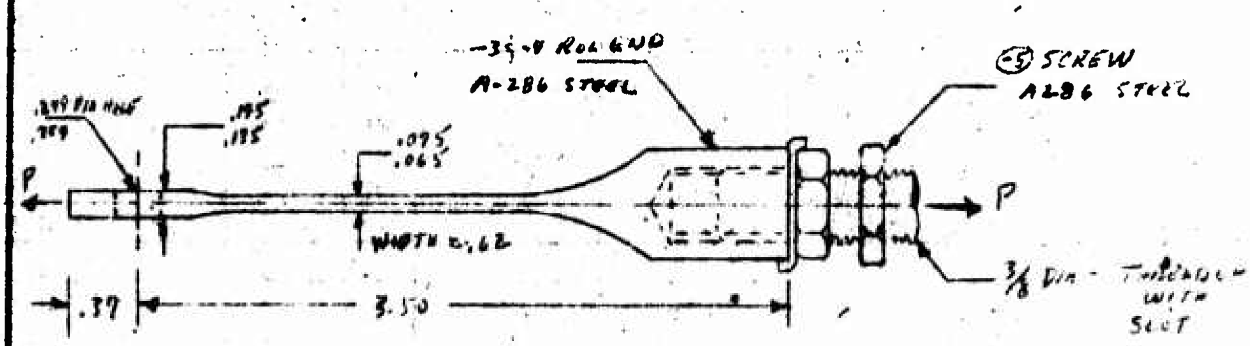
HUGHES TOOL COMPANY-AIRCRAFT DIVISION

ANALYSIS
PREPARED BY J. NEEDHAM 5/21/60
CHECKED BY
MODEL 285 REPORT NO. 285-13 PAGE 5.2.10.36

BLADE DUCT

OUTB'D DUCT C.F. TIE @ STA. 81.7

TURNBUCKLE ASSY - DWG. 285-0194



$P = 4600^{\#}$ ULT. (COVER-REV. COND. - 60% LOAD ON ONE SIDE)

$P = .60(3270 \pm 5) = 1960 \pm 3^{\#}$ LIM. (FATIGUE COND.)

STRESS ON MINIMUM SECTION

$f_t = \frac{4600}{.070 \times .62} = 106000$ psi

$F_{tu} = 85000 \times 1.5 \times .90 = 115000$ psi @ 800°F

$M.S. = \frac{115000}{106000} - 1 = \underline{.08}$

W.F. COND

$f_t = \frac{1963}{.0434} = 45200$ psi

BEARING STRESS @ 1/4 BOLT ATTACH

$f_{br} = \frac{4600}{.125 \times .140} = 131200$ psi

W.F. COND

$f_{br} = \frac{1963}{.035} = 56000$ psi

$F_{bru} = 200000 \times .88 = 176000$

$M.S. = \frac{176000}{131200} - 1 = \underline{.34}$

NOTE

HEAT-TREAT PER DWG. — USED IN ANALYSIS

MIN U.T.S. = 140000 psi — = 130000 psi
MIN Y.T.S. = 95000 psi — = 85000 psi
MIN ELONG = 12% — = 15%

} PER ANC-5a

OUTB'D DUCT C.E. TIE @ STA. 81.7

THRUBUCKLE ASS'Y - CONT'D

3/8 SPLICE SCREW - WITH SLOT .060 X .093 CORNER RADII = .015/.005

ROOT AREA OF THREADED 3/8" SCREW = .081 IN.²

F_{tu} = 85000 X 1.5 X .93 = 118500 psi @ 600 °F

P_T = 118500 X .081 = 9600#

MAX. LOAD = 4600# ULT (OVER REQ.)

WEIGHTED FATIGUE COND.

P_T = 1960 ± 3 # LIM.

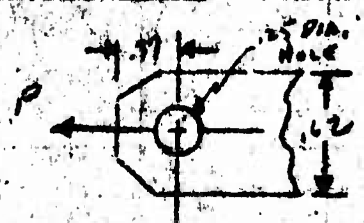
$f_t = \frac{1967}{.081}$ = 24 200 psi

AREA AT THREAD RELIEF

$A_{TR_{MIN}} = \frac{\pi}{4}(.305)^2 = .0732$ IN²

MIN. P_T = 118 500 (.0732) = 8660#

THRUBUCKLE END



P = 4600# ULT.

A_t = 2 (.62 - .25) .135 = .050 IN²

W/D = .62/.25 = 2.48 K_t = .92

$P'_{tu} = K_t F_{tu} A_t$ = .92 X 115000 X .050 = 5290#

$$M.S. = \frac{5290}{4600} - 1 = .15$$

▲ F_{tu} @ 800 °F. REF. 1

CLEVIS - OUTB'D DUCT HOLD BACK.
DWG. 285-0196

AS A BOLT, THE CLEVIS IS EQUIVALENT TO A 3/8 160-180,000 HT. BOLT.

MAX TENSIONAL LOAD = 4600# ULT, ...

MAX SHEAR LOAD = 5580×1.5 = 8370#

ROOM TEMP. ALLOW. OF 3/8 BOLT - HT 160-180000

$P_S = 10500$# $P_T = 12700$

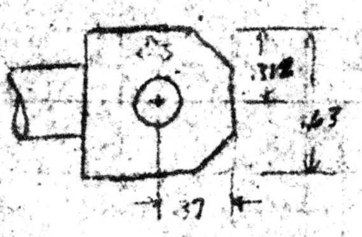
$R_S = \left(\frac{8370}{10500}\right) = .797$ $R_S^2 = .635$

$R_T = \left(\frac{4600}{12700}\right) = .362$ $R_T^2 = \frac{.131}{.766}$

$M.S. = \frac{1}{.766} - 1 = \underline{.30}$

TIES TO (-0194) TURNBUCKLE ASS'Y WITH A MS 20392-3-19 PIN. (DIA. .246 TO .248)

DIA. HOLE IN CLEVIS $^{.249}_{-.254}$



$W/D = .63/.25 = 2.52$ $K_t = .94$

$P_{TU} = .94 \times 160000 \times .25(.63-.25) = \underline{14,300}$#
@ R. TEMP.

MAX ULT. LOAD = $\underline{4600}$#

$D/t = .25/.125 = 2.0$

$a/D = .37/.25 = 1.48$ $K_{br} = 1.45$

PIN 20392-3-19 EQUIVALENT TO 1/4 BOLT HT 125,000 PSI

DOUBLE SHEAR = 2×3680 = 7360#

SATISFACTORY

285-013C DUCT ASSEMBLY

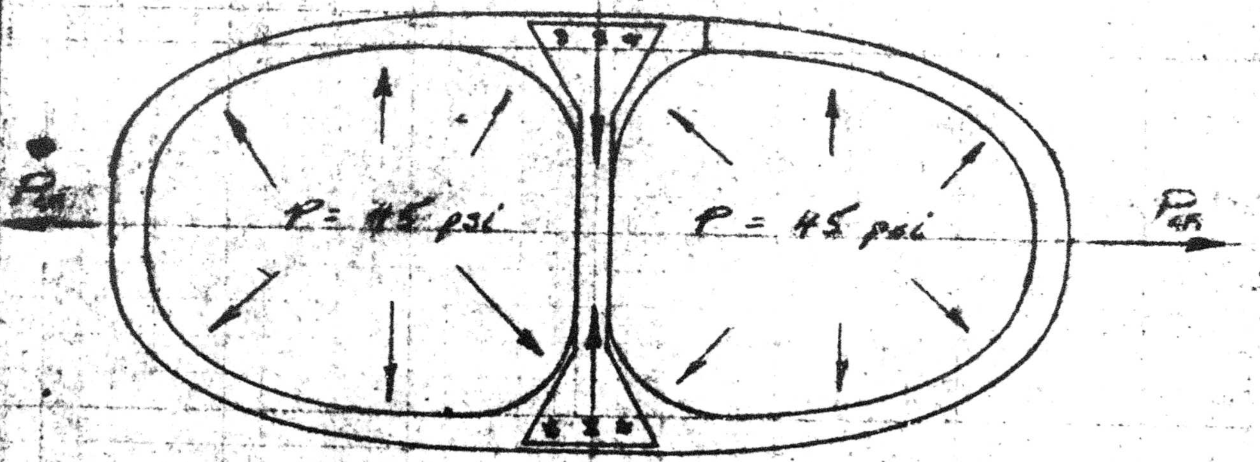
DUCT FRAME - STA 84.625

TEMP = 1040 °F

P = 40 psi (LIM)

P = 2.1 (40) = 84 psi (ULT)
PRESSURE ACTING ALONE

P = 30 psi (LIM.) IN COMBINATION WITH OTHER LOADS



STA	P	
80	-218# ULT	For $P_{A.F.}$ = 4600# ULT.
83	+976# "	
85	+493# "	

HUGHES TOOL COMPANY-AIRCRAFT DIVISION

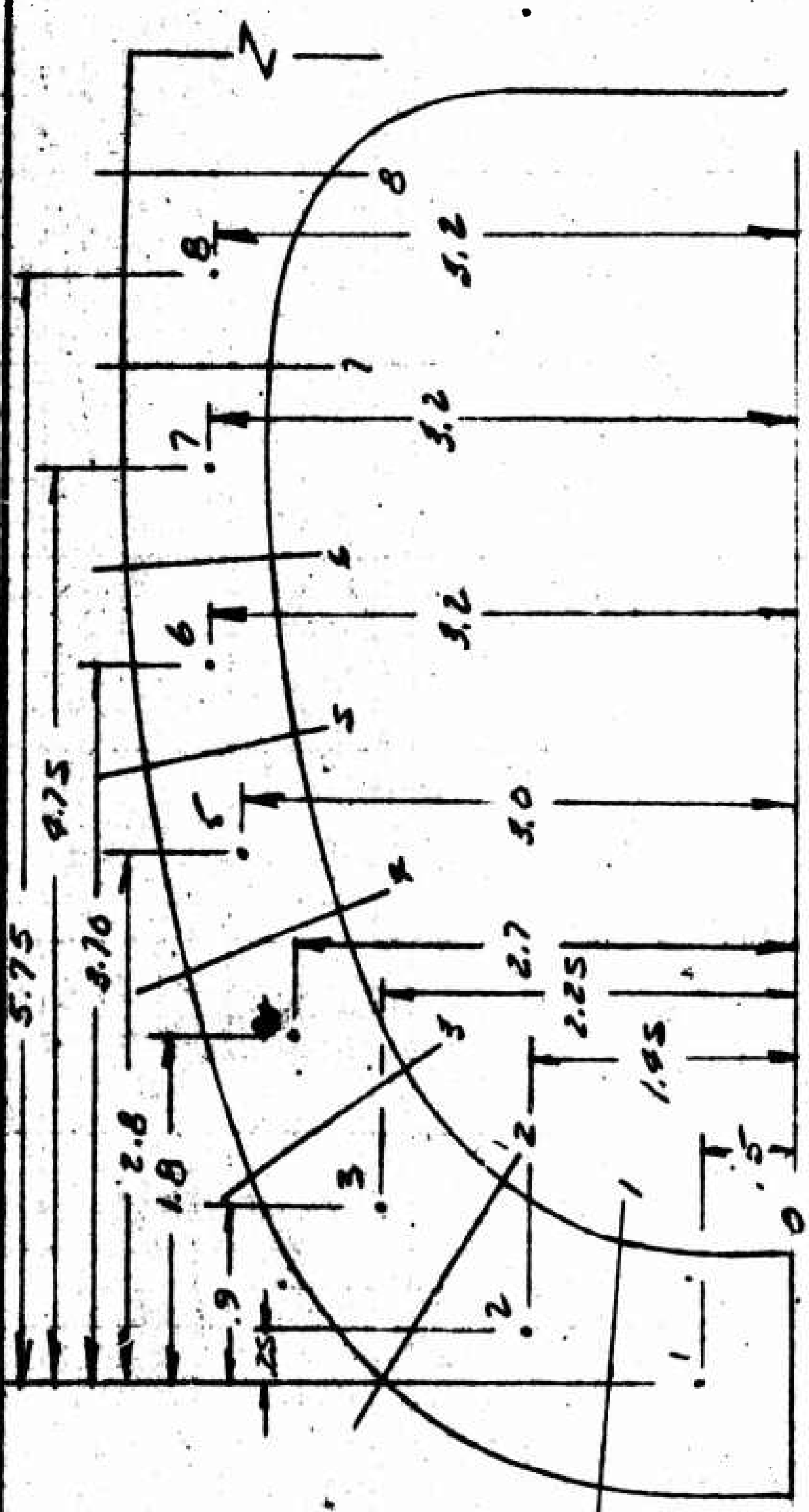
ANALYSIS HOT CYCLE | MODEL 285 | REPORT NO. 285-13 | PAGE 5.2.16.40

PREPARED BY W.L. ZICBES 5-25-46 | BLADE DUCT

CHECKED BY

285-0132

DUCT FRAME STA 82.875



HUGHES TOOL COMPANY AIRCRAFT DIVISION

MODEL: [illegible] REPORT NO. 285-13 PAGE 52.10.41

PREPARED BY N.L. [illegible]

CHECKED BY

[illegible] DUCT

LOADING

776# ult.

+M: TEN OUTB'D CAP

FRAME STA. 83

SEG	Ms	Mz	Rh ϕ	Σ		
0	0	+659	0	+659		
1	-244		0	+415		
2	-708		+52	+3		
3	-1100		+187	-252		
4	-1320		+378	-283		
5	-1465		+588	-218		
6	-1560		777	-124		
7	-1560		998	+97		
8	-1560		1210	+309		

HUGHES TOOL COMPANY - AIRCRAFT DIVISION

ANALYSIS HOT CYCLE MODEL 285 REPORT NO. 285-13 PAGE 6.8.10.72

PREPARED BY W.L. ZIKESS 6-26-60

CHECKED BY

BLADE DUCT

LOADING

$p = 84$ psi ULT.

+M = TEN OUTB'D CAP

+M

FRAME STA. 93

SEG	M_3	M_2	$R_H \cdot x$	Σ		
0	0	-61	0	-61		
1	-10		0	-71		
2	-79		+63	-77		
3	-192		+227	+26		
4	-328		454	+65		
5	-572		706	+73		
6	-810		933	+62		
7	-1135		1200	+40		
8	-1510		1450	-121		

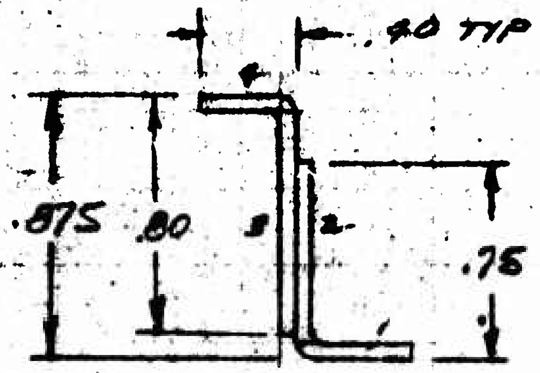
FORM 9708

285-0152 DUCT ASSEMBLY

FRAME STA. 93

SECTION @ SEG #3 (TYP)

MAT'L: INCONEL X .037 THK



ITEM	A	Y	AY	AY²	Iox
1	.00148	.019	28.1×10^{-6}	$.535 \times 10^{-6}$	—
2	.0264	.393	10400×10^{-6}	4080×10^{-6}	1300×10^{-6}
3	.0282	.456	12900×10^{-6}	5880×10^{-6}	1500×10^{-6}
4	.00148	.856	1270×10^{-6}	1090×10^{-6}	—
Σ	.05756	—	24598×10^{-6}	20585×10^{-6}	1800×10^{-6}

$$\bar{y} = \frac{.024598}{.05756} = .427 \text{ IN.}$$

$$I = .02585 + .0018 - (\overset{.0105}{.05756})(.427)^2 = .01715 \text{ IN}^4$$

$$f_b = \frac{Mc}{I} = \frac{283\,(.427)}{.01715} = 7050 \text{ psi}$$

MAT'L THICKNESS REDUCED TO .031 IN.

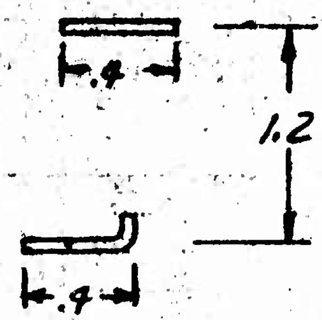
$$f_b \cong \left(\frac{.037}{.031}\right) 7050 = 8400 \text{ psi}$$

M.S. ⟶ HIGH

285-0132 DUCT ASSEMBLY

FRAME STA. 93.

MAT'L: .037 INCONEL X



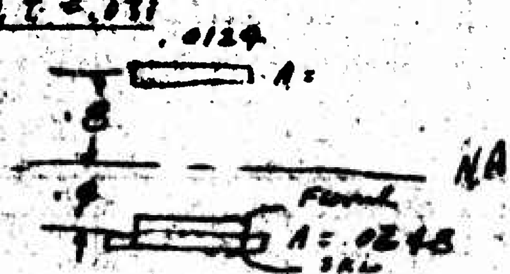
$$P_c = \frac{M}{1.2} = \frac{609-61}{1.2} = 498^{\#} \text{ (ULT)}$$

$$f_c = \frac{P}{A} = \frac{498}{(.4)(.037)} = 33700 \text{ psi (ULT)}$$

F_{cc} = b/t = .10 F_{cc} = 55,000 psi

$$M.S. = \frac{55000}{33700}(.80)^{*} - 1 = \underline{.30}$$

Mat'l t = .031



$$I = .0124(.8)^2 + .0248(.4)^2$$
$$.00795 + .00397 = .01192 \qquad M.S. = \frac{44000}{36800} - 1 = \underline{.19}$$

$$f_c = \frac{Mc}{I} = \frac{1100(.4)}{.01192} = 36800 \text{ psi comp}$$

$$f_t = 73600 \text{ psi ten}$$

F_{tu} = 150000 x .82 = 123000 psi ult. @ 1040°F

$$M.S. = \frac{123000}{73600} - 1 = \underline{.62}$$

* TEMP FACTOR REF. ①